NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

**LOGISTICS MODEL DESIGN IN MILITARY
OPERATIONS OTHER THAN WAR/FULL SPECTRUM
OPERATIONS**

by

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September 1997

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19980410 107

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE September 1997	3. REPORT TYPE AND DATES COVERED Master's Thesis	

4. TITLE AND SUBTITLE

LOGISTICS MODEL DESIGN IN MILITARY OPERATIONS OTHER THAN WAR/FULL SPECTRUM OPERATIONS

5. FUNDING NUMBERS

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Monterey, CA 93943

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release, distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Quantification of logistics requirements is essential to providing modeling and simulation with adequate logistics capability. Current models and simulations often rely on operator interface to accomplish the prioritization of logistics resources. However, this study shows that logistics requirements can be quantified based on the dimensions; Phase of the Operation, Level of Planning, Level of Support, and the Full Spectrum of Operations (FSO).

Believing differences exist in logistics priorities as these dimensions change, an experiment in survey form was given to logistics personnel in military commands as well as civilian relief agencies that have been involved in three types of Peace Operations; Humanitarian Assistance, Humanitarian Assistance/Disaster Relief, and Noncombatant Evacuation Operations. The goal was to derive a measure of the relative importance of particular logistics supplies or services in these Operations Other Than War (OOTW). The Method of Equal Appearing Intervals was applied to derive the measure of relative importance.

The analytical results show that as factors change in the operation, there is a change in the relative importance of logistics classes. In addition, as the operations change, there are a different set of priorities associated with each mission. The MEAI measurements can be applied directly in decision aids or in modeling and simulation efforts involving OOTW. The recommendations are to expand this approach by refining the survey and expanding the operations to include FSO.

14. SUBJECT TERMS
Logistics, Modeling and Simulation, Operations Other Than War (OOTW), Full Spectrum Operations (FSO), Method of Equal Appearing Intervals (MEAI)

15. NUMBER OF PAGES
121

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

LOGISTICS MODEL DESIGN IN MILITARY OPERATIONS OTHER THAN WAR/FULL SPECTRUM OPERATIONS

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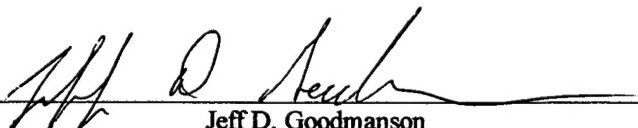
Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

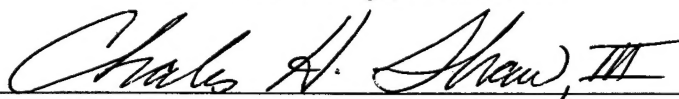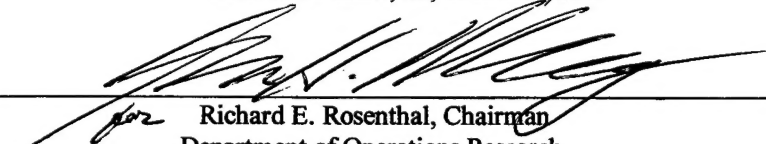## NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

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EXECUTIVE SUMMARY

Quantification of logistics requirements is essential to providing modeling and simulation with adequate logistics capability. Current models and simulations often rely on operator interface to accomplish the prioritization of logistics resources. The Unified Commanders and the Military Operations Research Society (MORS) have working groups to determine what logistics analysis tools exist or should be developed as an aid to the CINC's for planning and executing Operations Other Than War (OOTW) as well as supporting exercises.. Additionally, NATO and others are developing standard logistics packages needed to support an OOTW, reinforcing the need for a requirements structure and associated measures to apply to logistics resources. Determining these logistics requirements and measures has previously never been quantitatively approached.

The premise is that significant differences exist in logistics priorities along doctrinal and environmental lines. The doctrinal dimensions include the type of operation from the Full Spectrum of Operations (FSO), as well as the Phase of the Operation, Level of Support, and Level of Planning. The primary environmental dimensions, although there may be others, include the Duration, Climate, and Population Size associated with an operation at any particular point in time. An experiment in survey form was developed and given to logistics personnel in military commands as well as civilian relief agencies that have been involved in three types of Peace Operations; Humanitarian Assistance, Humanitarian Assistance/Disaster Relief, and Noncombatant Evacuation Operations. The purpose of this study is to evaluate a proposed structure and methodology that identifies the need for logistics representation in models and simulations along with appropriate measures for supplies and services across each dimension.

Categorical judgments and the Method of Equal Appearing Intervals (MEAI) were utilized to identify logistics requirements and derive measures of the relative importance of each logistics class of supplies or services. This was done for each of the three selected OOTWs. Along the doctrinal dimensions, frequency responses obtained from categorical judgements provided information to determine inclusion of a logistics class, establish command and control structures, and even determine appropriate levels of fidelity for each class of supply. Along the environmental dimensions, the scale values derived from applying the MEAI formed vectors in a Euclidean representation of the problem space which allow measures of relative importance for a logistics class and the sensitivity of each logistics class to changes along each dimension.

This study provides the proof of concept and serves as the basis to recommend further research. The analytic results show that it is possible to quantitatively define the logistics requirements in a portion of OOTW and that changes in the relative priorities for logistics occur across all three operations and both doctrinal and environmental dimensions. By expanding this method to include the FSO, models and simulations can be developed based on the priorities and the appropriate level of resolution can be determined more accurately. The priorities developed here can be associated with prepositioning of materials in potential hot spots or they can be used by planners in ongoing operations as a decision aid. The ideal situation is to build a variable resolution model based on the results so planners and operators at all levels have access to the information they need without being overwhelmed by the details. The methodology demonstrated in this research has the capability to meet these needs.

I. INTRODUCTION

A. OVERVIEW OF MODELING AND SIMULATION

Before embarking on an effort to model or simulate logistics requirements, it is necessary to briefly describe the differences between models and simulations. Models and simulations have been in existence for some time, but their definitions have been clouded by enhancements that have come from combining the two in practice. Moreover, while the uses of the two may often be similar, their development is definitely different. Where modeling is an attempt to represent the actual physical aspects of a situation, simulation can be considered an experiment. Models may be used to represent an existing system or the idea and design for a new system. Modeling's objectives may be to improve the performance of the system or to identify the most desirable attributes of a new system. Generally speaking, however, the purpose of a model is to optimize the systems' performance. Simulation, on the other hand, attempts to imitate the system over time. There may be models used within a simulation; but, the objectives of the simulation are to provide statistical information that can be used in analysis of various aspects of the system. [Ref. 1] It is also important to remember that neither a model nor a simulation can be considered reality. They are only as close to reality as the amount of resolution and fidelity with which they were designed.

The most familiar type of models in Operations Research are mathematical models. A system can be viewed as a number of variables. Based on the complexity of the system, the number of variables necessary to represent that system can get quite large; but, models may be simplified by finding a dominant set of variables within the system. After identifying the variables that affect the system and their relationships to one another, the

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model is much simpler to work with and is reflected in a mathematical expression that represents system parts as variables and their interrelationships as mathematical functions. The introduction of improved computational methods over time has enabled the inclusion of increasingly large numbers of variables in models, which enable closer approximation to reality and solution of more complex models. However, it is not always possible to define the appropriate variables or mathematical relationships between those variables, especially when they are highly stochastic. Defining the necessary variables is usually determined either while constructing the model or in comparing the results of a model to actual historical results.

When the mathematical computations required are too complex for an optimum solution, heuristics can be employed. The heuristic method utilizes intuition, simplifying assumptions, and empirical rules that will allow an approximation to a solution. Although it may not be possible to determine the optimum answer, heuristics make it possible to improve the system being modeled through approximation. Another way to represent a system that is too complex to be mathematically modeled or cannot be optimized is by simulating it.

As stated previously, simulation can be considered an experiment. In general, the system is decomposed into manageable parts. These parts are linked through their process interactions with one another and when the system is operated over time, the effects of these relationships can be measured and, in turn, become the results of the simulation. Again, defining the purpose for the simulation is crucial to determining how to view the results. When the simulation is replicated or run repeatedly to obtain a sufficient sample of measured results, those results can be statistically examined. When excursions are

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conducted, such as adding additional parts to the simulation or changing the process interactions of one or more parts, sensitivity analysis can be performed on the results to determine how even slight changes in the system affect its performance and potentially how to best improve the system performance.

An example of the use of simulation is in representing combat. It is impossible to represent all combat entities and their interrelationships at a high level of resolution using a mathematical model. When the processes are highly stochastic and the number of variables are large, it becomes increasingly difficult to rely on a single mathematical model. Mathematical models can represent a part of the force, such as transportation. However, when the analytic goal is to determine how the overall combat scenario will react to an individual combatant's decision or a movement by some portion of the force simultaneously, it often becomes impossible to describe the relationships and variables mathematically. Simulation is a way to analyze and train for combat when mathematical models cannot represent the total force. Many of the original wargames can be considered manual simulations. Using stochastic and Monte Carlo methods and clear rules for how a combat component could operate, the results of the wargame would be based on the interaction over time of each of the parts. Development and implementation of a simulation can be time consuming and expensive to undertake; therefore, the analytic goals must be clearly defined at the outset.

B. HISTORY

1. The Origins of Combat Models

Wargames and models for military use trace their roots back to the late 1800's; but, since their origins were deeply rooted in the traditional strategy and tactics of fire and maneuver, logistics were rarely considered. Attempts during World War II to implement logistics in these games and models were thwarted because their inclusion slowed the play of the strategists and tacticians. The primary purpose of modeling warfare was to examine the results that different strategies or tactics might exert; but, the question of a warfighter's effectiveness when ignorant of his logistics assets, requirements, and capabilities remains. Therefore, while wargaming was a valuable tool used to examine combat, the manifest need to make these models and games as realistic as possible persisted; that is, to properly model reality, logistics would have to play a role.

Changes in military modeling and simulation are marked by periods of major conflict. Since the inception of wargaming in the early days of the German General staff during the Franco-Prussian War (1870-1871), models and simulations have been accepted as viable training and analysis tools for use in the military community. The German General staff used models as a way of conducting campaign analysis after World War I where mathematical models were effective in computing requirements, a logistics related function.

2. The Maturation of Combat Models

The birth of operations research as a separate field occurred in World War II. Professor P.M.S. Blackett and his group of scientists, known as "Blackett's Circus," were using models in England to determine how best to distribute their limited resources to

provide for the defense of the nation and where improvements in combat systems could be made. [Ref. 1] Most of the applications were related to improving radar or anti-aircraft weapons; but, at least one of their field sections during the war concentrated on jungle warfare, logistics and maintenance. By 1943, the value of operations research was clear and there were 174 scientists employed in the British Army's Operational Research Group (AORG). [Ref. 2] However, the goals of these studies were primarily aimed at solving strategic level problems. Very few of these efforts concentrated on the problems experienced by tactical level commanders. The move in the AORG was one to greater fidelity in solving these strategic problems.

Scientists in the United States, aware of the success of Blackett's Circus, soon began to emulate British efforts and found additional applications for operations research tools. Logistics problems were the focus of many of the initial efforts. Development of scheduling and movement models provided very useful information to the logistician and warfighter alike. Much of development was due to the need to defeat the German U-boat campaign against merchant shipping. Thomas Edison actually created a simulation technique where players moved pegs on a board to get convoys safely to port. This technique reinforced the effectiveness of convoys if employed properly. Some of the lessons were simple. The convoys should move through danger areas only at night and the shipping routes that had been used for many years should be changed. [Ref. 3]

The success of these rudimentary models lead to the creation of applications more directly related to combat and the post war years found operations research techniques used to test new weapons and tactics rather than using field tests. The Navy was using a simulation called the "attack evaluator" to overcome the high cost and difficulty in

coordinating sea trials. [Ref. 3] Projects designed to evaluate systems had a great impact on how operations research would be used in the military. Throughout the 1950's, improvements in the methods used for weapons and tactics analysis were top priority. This was also the period of time when models began to be used in the business sector. While the military had shifted its focus to evaluating systems, the business sector was beginning to use models for analyzing transportation, city planning, and communications. Eventually, the split between applications in the military such as deterministic Lanchester methods and the development of the simplex method for business applications occurred as an example.

3. Cold War Modeling and Simulation

With the value of Operations Research established in the United States, military models and simulations were developed around three key factors affecting the world situation during the Cold War. First, there was a single, predominant enemy. The capabilities of the former Soviet Union provided definable targets against which to develop these tools. It was unnecessary to consider several different enemies because even a coalition of communist countries could be grouped by the similar weapons and tactics they would employ. Second, the enemy's capabilities and capacity could be estimated with relative certainty. The composition of their units was understood and the possible tactics they would employ were relatively well defined. Third, the geographic area in which a conflict could take place was also relatively easy to estimate in a bilateral world. When most countries were aligned with one side or the other and the majority of actions against enemies would be undertaken by individual nations, the simulation or model could easily be constrained to the relatively simple two-sided form.

Cold War models were primarily concerned with combat and seldom considered the logistics required to sustain the battle. Models that did attempt to incorporate logistics often ensured that an on/off switch was available for two reasons. First, if players were involved in combat training, logistics play was often eliminated to avoid overburdening the commander with information that was considered nonessential. Second, imposing logistics calculations on top of the large number of computations already included in combat simulations could slow a system down to unacceptable levels.

In the 1960's, budgetary constraints were introduced in military models. In the Navy, this meant that fleet capabilities and logistical requirements were being evaluated to determine operational readiness. [Ref. 3] Additionally, the war in Vietnam was also beginning. As the U.S. became more involved, it became apparent that some of the most valuable models and simulations were those which concentrated on counter-logistics. The counter-logistics models and simulations were tools used to find the optimal method of interdicting the flow of supplies to the North Vietnamese Army and Viet Cong from North Vietnam, Laos, and China. Again, modeling and simulation began to focus on logistics as a Center of Gravity in the war.

4. Modern Military Modeling and Simulation

Following the Vietnam war, most logistics efforts were once again produced in isolation. Determining pre-positioning requirements of fuel and ammunition became the main goal of logistics models. In the combat arena, the focus again became development of more sophisticated tools to evaluate systems and strategies. In the 1970's, complex board game simulations were conducted for training and analysis of combat actions. When the computer architecture to support these complex fire and maneuver battles

became available, many of the intricate rules of the game were still difficult to implement. Therefore, the focus shifted to ensuring that combat could be accurately portrayed, and the logistics portions would be temporarily left out. However, as computing power increased, the desire to improve search and detection, terrain representation, and mobility as well as increase the level of resolution to represent individual soldiers or units as entities was greater than the desire to include logistics in the simulations.

Many models took the rules of a deterministic, large force type battle or modified board games for smaller unit simulation and pitted two known entities against one another. If logistics were included, they were modeled in gross units such as thousands of gallons for Class III (Petroleum, Oil, and Lubricants) and cubic tons for Class V(Ordnance); but, these low resolution models did provide useful information on the possible outcomes and courses of action. Advances in modeling and simulation began to come primarily in the form of improved attrition rules, search algorithms, and terrain representation in addition to other improved algorithms and a computer architecture capable of handling the large number of computations that were needed to model combat and improve the graphical user interfaces. However, these models focused primarily on the fire and maneuver processes of warfare and continued to ignore the possible limitations imposed on these operations by a lack of logistics support.

Those modelers that were successful in convincing the military to include logistics in traditional combat models often used a bean-counting or at most a simple Monte Carlo method to determine usage rates and then only for the Class III and Class V supplies. Some effort was made to improve battle damage assessment and maintenance returns for Class VII (Vehicles and Support Equipment) primary weapon systems; but, these were

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still generally limited to a simple two-step Monte Carlo method. Those models that did incorporate distributions usually had insufficient data to support them. Besides relatively inaccurate methods of computing logistics factors, the logistics portion of the model or simulation performed independently, resulting in a model or simulation that was not being run as originally intended. The logistics model in these cases amounted to little more than a patch into an existing system.

History has repeatedly shown how logistics truly limit the warfighter even to the extent of its becoming the critical variable of many campaigns and battles. A realistic aspect of training those who will fight the next war is logistics. In addition to the need to couple logistics with combat, the reality of the combat models has also been challenged. Initially, major conflict was the concern and often the only reality; but, current doctrine regarding employment of forces requires modeling and simulation across the Full Spectrum of Operations (FSO). FSO encompasses operations from Civic Action in a permissive environment to Global War. Suffice it to say, the requirements and situations encountered in a specific operation can be very different.

A system that cannot coherently integrate its parts is useless and a system running in parallel, using time and the size of the force as the only common factors might as well be run separately. In fact, this practice contributed to the ultimate separation of logistics from the combat modeling and simulation communities. Within the logistics community, tools were developed to assist planners and tactical level logisticians in analysis of their own tasks and evaluation of possible courses of action in wartime. These tools included transportation models which were created to evaluate the feasibility of logistics plans associated with combat scenarios. Unfortunately, the impact of these logistics models

affected how the combat commander responded in wartime and it seemed likely that the warfighter and logistician might never be linked together in training and analysis of missions. Two principal components in any wartime scenario were now on separate tracks in the modeling and simulation community.

C. PRESENT

1. The Impact of Recent Operations

Desert Storm has significantly influenced how the U.S. modeling and simulation community will view future wars. It is important to remember that it is unlikely the next war will look anything like Desert Storm; but, Desert Storm gives analysts a point from which to begin excursions in how today's people and equipment can be expected to operate. It served as the only major "field test" of equipment and personnel in the last two decades, and has provided useful information from which to review and update current models and simulations. Once again, war had increased the need to properly assess logistics requirements. The advances in modeling and simulation by 1990 were significant and it was obvious that logistics needed to play a larger role in the training and analysis tools. The lessons learned from Desert Storm continually emphasized the importance of logistics, and it was clear that something had to be done to incorporate logistics planning in combat scenarios.

In addition to Desert Storm, there were a number of operations to which U.S. forces were committed, but not in a traditional sense. As the U.S., United Nations (UN), and North Atlantic Treaty Organization (NATO) each began to play a larger role in the emerging world, they became involved in many operations that could not even be classified as conflict. In fact, between 1986 and 1996, there were 208 non-traditional

operations conducted, with the annual number of operations increasing each year. Places like Somalia, Haiti, and Bosnia were now the "hot spots" on the globe and the missions were very different from what the military had traditionally trained and planned for. The idea of coalition or multinational, non-traditional warfare where many nations make up the force is not new; but, the way these forces are employed, working side by side with one another, is a new way to operate. Forces sharing resources as in the NATO and UN concept of Lead and Role Specialization Nations was a revolutionary idea. The concept held that one country, with specific capabilities and requirements, was responsible for a geographic area or would provide a single resource like fuel to all forces regardless of service or nation. Multi-national, multi-sided force structures did not look anything like the structures available in the combat models and simulations at the time of Operation Desert Storm.

2. Requirements in a Changing World

These changes prompted the modeling and simulation community to adopt three basic initiatives. The first shift was from defined operations to undefined operations. The primary plan for an operation, the Operational Plan (OPLAN) was relatively easy to draft before Desert Storm because the world was, for most intents and purposes, a known entity. The operation would be designed as a military endeavor to accomplish narrow military goals. The new requirement was the need to respond using crisis action procedures to any location in the world and engage in operations never intended to be military in nature. This led to the second initiative, away from conventional combat missions to other operations with new and unconventional roles for the military. The argument can be made that the military has always participated in peace operations; but,

they were never involved in peace operations on the scale seen today. The reliance on forces strictly for combat came to an end as the military became a primary care giver for a population in distress. The third shift was from operations that exclusively involved military personnel to operations that had diverse military forces and civilians working side-by-side. In many cases, an operation could actually be controlled by the U.S. State Department with the military only involved in a supporting role. The conflicting charters of the military, Non-Government Organizations (NGO), and Private Volunteer Organizations (PVO) can also make mission accomplishment difficult.

Lessons from various operations document the incompatibilities of military and civilian organizations. For example: "...many relief organizations and individual relief workers are not too receptive of military forces moving in and taking charge by sheer mass and concentration (during the Rwanda crisis, the military did some great things, but military contracting officers drove the prices out of sight in Uganda)..." [Ref. 4] or "Because multinational forces are ad hoc coalitions of the willing, planners must recognize the reduced tempo with which a coalition force conducts peace operations." [Ref. 5] These cultural differences might make the transition difficult; but, understanding the mission of the other organizations involved can help to complete those missions and help the modeling and simulation community understand their underlying character.

3. Ongoing Efforts

The Joint Training Confederation (JTC) and Joint Simulation System (JSIMS), as well as the idea of "Focused Logistics" in Joint Vision 2010, made it clear that it was in the interest of the Commanders in Chief (CINC's) to move toward integration, not only of the logistics, but of the individual service models themselves. Joint warfare could

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characterize how to fight the next war. To train the way the United States was going to fight future conflicts would require joint modeling and simulation. Unfortunately, each Service had their own versions of "legacy" combat models which often used different programming languages. These so called "legacy" models and simulations had evolved within the Services over many years and resulted in millions of lines of computer code that had been modified and added to whenever it seemed necessary. The U.S. Army's Janus, a medium to high resolution wargaming simulation, is a good example of a legacy model.

The first version of JANUS was developed by Lawrence Livermore National Laboratory (LLNL); but, each of the Army's Training and Doctrine Command (TRADOC) and Analysis Centers (TRAC) eventually produced their own version of JANUS. This multi-track development occurred because each time a Center saw it necessary to make additions or modifications, they did so without a Central Design Activity (CDA) to oversee the development and usually failed to distribute the new version to one another. A command being served by one particular Center had specific goals in mind and the Center typically only responded to a customer's request. When a change was forwarded, the user also had the ability to decide whether or not it would be implemented. [Ref. 6] It is easy to see how this became a major issue in one Service alone. Compound this problem by the four Services and their respective simulation and modeling sites, each using their programming language of choice, and it becomes clear that the JTC and JSIMS programs had a difficult road ahead.

The focus of both JSIMS and the JTC was training forces through simulation. Although some analysis could also be conducted to support emerging doctrine, for example, in the Advanced Concept Technology Demonstrations (ACTDS) and Advanced

Warfighting Experiments (AWEs), the first step was to define all requirements for training and analysis alike. A 1995 conference was held by the Joint Warfighting Center (JWFC) and Defense Modeling and Simulation Office (DMSO) to determine how JTC and JSIMS would approach the problem and to set priorities on their requirements. There was little agreement on which modeling and simulation tools in use by the services were actually the best representatives of the Services' combat intentions. Through these conferences, the Services finally agreed in 1996 on which simulations they would use to represent their Service in JTC. The Air Force contributed the Air Warfare Simulation/ Revised (AWSIM/R), the Navy contributed the Research, Evaluation, and Systems Analysis (RESA) model, the Marine Corps contributed the MAGTF Tactical Warfare Simulation (MTWS), and the Army contributed the Corps Battle Simulation (CBS) as their respective Service representations. Additionally, three other models were incorporated in the confederation: an electronic countermeasures/electronic warfare simulation, the Joint Electronic Countermeasures and Electronic Warfare Simulation (JECEWSI); an intelligence simulation, the Tactical Simulation (TACSIM); and a space warfare simulation, the Portable Space Model (PSM). Unfortunately, few of these simulations included logistics at a level of resolution appropriate to joint simulation. The exception was the Combat Service Support Training Support System (CSSTSS). CSSTSS was the logistics functional model for the U.S. Army's Corps Battle Simulation (CBS) concentrating on supporting ground troops.

Those models and simulations that included logistics information generally concentrated on the simple calculations mentioned earlier; the Class III (Petroleum, Oil, and Lubricants) and Class V (Ordnance) supplies along with some of the Class VII

(Vehicles and Equipment) maintenance returns. Although these items usually impose a major constraint on military forces, they were generally calculated using a bean-counting format; that is, to simply deplete resources over time by some estimated, fixed usage rate without taking into account the possibility of a changing demand. When an operation or exercise was analyzed using this approach, the result for logistics was usually a new estimate of the usage rates. Although the Army has used logistics planning factors for years, the newer combat scenarios were proving that something was missing in the estimation process. The shift from emphasizing combat to emphasizing other operations and logistics in simulation was continually being stimulated by the CINCs desire to design exercises around a humanitarian crisis as part of a disaster or some other Peace Operation as the start of the exercise.

4. Difficulties in Implementing Logistics

Unfortunately, logistics improvements in simulation remained seventh on the CINC's JTC Integrated Priority List (IPL) at JWFC and logistics functions in exercises were still being accomplished, mostly off-line, by operators or controllers rather than simulating the key processes. CINC exercises such as Baltic Challenge, Fuerzas Unidas, Fuertes Rescate and the NATO Exercise Cooperative Safeguard highlighted the need to include more realistic logistics functions. Not only were the supply functions necessary; but, field services, medical, engineering, maintenance, mortuary affairs, security assistance, and transportation functions needed to be included in the models and simulations if the models were going to realistically reflect unconventional types of operations. Moreover, the complexity and unconventionality of the operators, suggest that it is not only a

problem of defining how to model these functions, but also to determine at what level of resolution these functions should be represented.

As mentioned previously, one of the first instances of a detailed logistics simulation came from the Army. The Army used the Corps Battle Simulation (CBS) in its training exercises since the mid 1980's and the Training and Analysis Center at Fort Lee, VA (TRAC-LEE) worked to provide their combat service support units with the same type of logistics training models for exercises. The Combat Service Support Training Support System (CSSTSS) was the result. This model allowed high-resolution simulation of all classes of supply and most services which were then tied into the CBS exercises. The simulation capability of CSSTSS allowed the combat commanders' reactions to be simulated as well as the supplies, medical support, transportation, maintenance, and personnel functions. However, the amount of computation necessary to conduct both ground combat and logistics in the simulation, induced exercise coordinators to use the "off switch" to satisfy the commander conducting the exercise. This response is the result of two factors. First, the Army, possibly more than any other service, uses training exercises to evaluate the proficiency of a commander. There will be reluctance to include logistics in these exercises as long as a commander is judged based on performance during them. Secondly, since the exercises are generally conducted as an evaluation of the combat unit's Mission Essential Task List (METL), sustainment or mobility tasks are usually given a lower priority or even ignored altogether. As long as exercises are designed to evaluate only how well a commander can conduct combat, there will be no urgency to complicate the training with volumes of logistics information.

There were other attempts to include logistics in exercises. Global '94 was a game conducted at the Naval War College designed to put logisticians in the joint wargaming environment. The game's charter came from the Directorate of Logistics on the Joint Staff (J-4) and the overall objectives were to provide useful logistics information to the Joint Warfighting Capabilities Assessment (JWCA) process. The preparation for the game by the participants proved that development and analysis before gaming a scenario was the only way to ensure valid and trustworthy results. Of the lessons learned, the most important to logisticians was that "emphasis on logistics issues in joint games could complement the other ongoing assessment processes." [Ref. 7]

This was not the only effort the Navy undertook, and including logistics in wargames has continued; but, the efforts are usually focused on a particular issue: whether that be related to manpower, ordnance, or transportation. The ultimate goal in modeling and simulation needs to be incorporating all aspects of logistics in each possible scenario as well as operations and combat.

5. Impact of the Changing World Situation

The current world situation looks little like the past. The Post-Cold War world is still evolving and this greatly affects the modeling and simulation community. The political situation alone has greatly affected how forces today will be employed. There is no longer a single enemy to fight. The role played by the Soviet Union has been replaced by rogue nations, terrorists, drug lords, civil insurgents, natural disasters, or combinations of such entities. Homogenous forces have been replaced by multilateral, multinational, coalition forces, along with Non-Government Organizations (NGOs) and Private Volunteer Organizations (PVOs) and this complicates any attempt to provide forces with

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useful modeling and simulation analysis or training. Estimates of the enemy's strength and even our own capabilities are difficult to determine given the vagaries of coalition warfare, the Inter-Agency (IA) process, and the uncertain state of day-to-day international relations.

6. CINC Initiatives

One CINC took an interest in the modeling and simulation of Operations Other Than War (OOTW). In 1995, the United States Pacific Command (USPACOM) sponsored the first Operations Other Than War/ Full Spectrum Operations (OOTW/FSO) modeling and simulation requirements workshop and held several conferences through 1996. The result was a report describing the requirements for analysis tools to support decisions at the strategic and operational levels for these missions. The follow-up to these seminal efforts took place in January 1997 and produced a list of particular goals through its working groups. Regarding logistic and mobility planning tools, USPACOM sought to support a 6-8 hour turn-around from a no-plan situation. The desire was to address general deployment scheduling requirements for national, foreign military, and non-military elements. Work related to foreign military forces was of interest in the past; but, this was the first time the introduction of government organizations or other non-military organizations was recognized. In response to USPACOM's requirements, the Military Operational Research Society (MORS) formed working groups to begin developing analysis tools. The latest MORS report highlights, "...the needs for analysis tools in particular areas in addition to providing a list of requirements for analytic support tools for OOTW planning." [Ref. 8] The efforts by the MORS group and those taking place in the

training community, highlight the desire to improve current modeling and simulation to capture the processes involved in OOTW.

D. FUTURE NEEDS

Although the work of MORS addressed analysis and the efforts in JSIMS and the JTC focused on training, the manifest interest in OOTW is evident. The problem is not simply how to represent various entities in models and simulations, but at what level of resolution they need to be represented and how the operations themselves should be characterized. The tremendous amount of analysis since Desert Storm has attempted to characterize the next conflict that U.S. military forces will face and what the future mission of those forces might be. Much of the analysis is geared towards determining how to maintain the operational tempo (OPTEMPO) of military units while reducing the budget. However, the first step in accomplishing this is to define the full range of missions that could be expected to occur, then to look within those missions to determine their requirements.

The current terminology most commonly used is Full Spectrum Operations (FSO), where individual operations range from a port visit with no conflict involved to Global Theater Nuclear War. Many analysts saw the need to further decompose this "full spectrum" for their analysis. MORS, in their study, used Peace Operations, Lesser Regional Conflict, Major Regional Conflict, Global Conflict, and Nuclear Conflict as the subdivisions. The break between these divisions is not consistent from one study to the next, but most seem to agree on the terminology. The real confusion derives from the reality that the operations are usually conducted simultaneously and in concert with many

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participants. That is, a mission to feed hungry refugees may escalate to a combat mission, where the conflict quickly overshadows the need to save the population, but does not eliminate the need to complete it.

Joint Vision 2010 (JV2010), a document in which the Chairman of the Joint Chiefs of Staff (JCS) projects where the services need to be in the future, emphasizes four operational concepts to accomplish future missions. The concept which this thesis supports is "Focused Logistics." JV2010 is designed to guide the military in preparing for the future. The "Imperative of Jointness" and "Multinational Operations," is a significant departure from traditional JCS guidance on warfighting. The guidance directs, "...we must be fully joint: institutionally, organizationally, intellectually, and technically." [Ref. 9] In addition to jointness, the ability to integrate and improve interoperability with other nation's military forces as well as U.S. and foreign civilian organizations is also paramount. The impact this concept of operations has on logistics is obvious. The need to provide support and sustainment for forces composed of both U.S. and foreign military personnel as well as civilians in peace operations is greater than ever; but, the modeling and simulation community, while having tried to answer the call for some time, has done so with little success.

Across the Full Spectrum of Operations, the most difficult operations to characterize, and the focus of this study, are Operations Other Than War (OOTW). In the MORS divisions, OOTWs are considered permissive Peace Operations. The tools for training and analysis of combat operations have been well-developed to this point and have been adequately represented in the JTC. However, because sustainment enhancements were considered complete when CSSTSS was added to JTC, the need to

extend sustainment capability to other services went unfunded. [Ref. 10] Again, logistics functions took a much lower priority in the JTC. The goal for the future is still to add the additional logistics functionality necessary to ensure JTC can be utilized as a complete combat training and analysis tool; but, there is no indication that the functional areas of the JTC will be reprioritized. Logistics are given a more favorable place in OOTW consideration because these operations are more logistically oriented.

To serve the needs of the analyst, OOTW models and simulations will have to include detailed logistics functions. The combat models also need to implement logistics fully; but, in 1996 the initial sustainment enhancements in the JTC were considered complete and the extension to the sustainment requirements was still not funded.

E. PROBLEM DEFINITION

For the professional logistician, the need for OOTW training and analysis tools would appear to be an opportunity for logistics to take the lead in modeling and simulation. The problem that confronts the modeler today is that the dimensions of the FSO requirements and the logistics aspects of those operations are still undefined. The approach used in the present study is based primarily on the MORS work and expands the breakdown of mission types on the Spectrum of Operations along three additional, primary dimensions which are Phase of the Operation, Level of Support, and Planning Level. It is not enough to say that the logistics support necessary for a mission is simply based on the goals of a specific type of mission. It would not be sufficient to determine only the military requirements since modeling and simulation requirements today demand implementation of multiple sided play with sides such as neutrals, NGOs, groups of refugees, or other entities. Although the most recent version of the Joint Theater Level

Simulation (JTLS) has implemented ten-sided play with a capability to split those sides into twenty factions, there are no databases for those sides. To accomplish multi-sided play, it is necessary to understand how organizations other than the U.S. military accomplish their missions so that their actions might be properly modeled.

The skills, material resources, and requirements of other country's militaries and non-military forces must be properly represented. Civilian and government organizations have their own resources to contribute to a Humanitarian Relief effort. For example, the Office of Foreign Disaster Assistance (OFDA) has stockpiles of materials in forward locations around the world. These are the resources that are used when OFDA's services are provided during a foreign disaster relief operation. The Federal Emergency Management Agency (FEMA) has the same types of resources for domestic operations. With JV2010's goal of providing more efficient and cooperative efforts, redundancy that exists when several organizations are attempting to provide assistance in the same operation must be eliminated. NGO's have been working side-by-side for some time. The truly new participant in OOTW is a large military force.

One way to define the logistics requirements would be to survey as many logistics professionals in as many of the organizations that participate in OOTW as possible; but, it was necessary to define the survey dimensions first. The salient, primary dimensions chosen were Phase of the Operation, Planning Level, Level of Support, and the Spectrum of Operations which will be referred to as doctrinal or Level I Factors.

1. Phase of the Operation

The doctrinal phases of an operation describe various activities that exist in every type of operation. However, these activities normally happen over differing periods of time from one operation to the next. For this study, the phases were defined in groups that have common logistics requirements. These groups or periods, in order of occurrence, include:

- Phase I: Planning, Pre-Deployment, Mobilization,

- Phase II: Deployment and Surge,

- Phase III: Operations and Sustainment, and

- Phase IV: Redeployment and Demobilization.

In some cases, these phases may be broken down into their subcomponents and it is not unusual to see six or seven distinct groups or periods. The use of these phases will be explained in more detail in Chapter III. B. 2. on methodology.

2. Planning Level

The various planning levels seemed obvious by military standards, but became more difficult to similarly define for the civilian organizations. The Universal Joint Task List (UJTL) breaks joint operations tasks into three distinct levels, the national or strategic, the operational, and the tactical levels.

a. National or Strategic Planning Level

The first, national or strategic level is, "...the level of war at which a nation, often as a member of a group of nations, determines national or multinational (alliance or coalition) security objectives and guidance, and develops and uses national resources to accomplish these objectives...." [Ref. 11] When used in the survey, this definition had to

be related to a similar level in civilian organizations. The national/strategic level was simply defined as an item that would require the approval or specific consideration of U.S. leadership or the international headquarters of a non-military organization.

b. Operational Planning Level

The Operational Level is defined as, "...the level of war at which campaigns and major operations are planned, conducted, and sustained to accomplish strategic objectives within theaters of operations...." [Ref. 11] For the purposes of the survey, this level indicates those items that would need approval or specific consideration by the leadership in the regional area of the operation.

c. Tactical Planning Level

The third level used by the military is the Tactical Level. This is, "...the level of war at which battles and engagements are planned and executed to accomplish military objectives assigned to tactical units or task forces...." [Ref. 11] The survey defined items at the Tactical/Unit Level as those which are best handled by the individual units providing assistance within the region of the operation.

3. Level of Support

The second dimension of the problem concerned which organizations could best provide resources for an operation. To be efficient, the source of the materials and manpower necessary to conduct an operation must be identified. Using historical data from past operations, whether the military was involved or not, most of the key participants or organization types were easily identified. These participants were

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partitioned into five groups that provided logistics support for past operations. The five groups were:

- Military. The military has participated in over 200 of these operations since 1986. Still a small number compared to the number of times organizations such as the International Committee of the Red Cross (ICRC) participated.

- OFDA/FEMA. These U.S. Government Agencies represent the primary U.S. assistance in foreign and domestic disaster relief operations, respectively.

- Coalition Forces. This category was intended to represent foreign military and other forces that usually fall under a UN or NATO charter. Foreign military personnel may offer special services in the region of the operation or resources that would be difficult or expensive to provide from the U.S..

- NGOs/PVOs. There are many civilian organizations that provide a wide variety of assistance. Some provide assistance to women and children, while others provide planning and management assistance to teach a population how to start agriculture programs in their community.

- Host Nation. This group was difficult to categorize because their ability to provide support is heavily impacted by their infrastructure and political stability.

4. Spectrum of Operations

The organizing principle with regard to categorizing the Spectrum of Operations is that the operations have been decomposed with regard to the common attributes and tasks associated with past missions. The large groupings, such as Peace Operations have also been subdivided creating a number of subordinate missions such as Civic Actions, Disaster Relief, and Humanitarian Assistance. These subordinate missions are Peace Operations; but, they have uniquely different requirements.

Figure 1 depicts the specific logistics requirements as they exist in the dimensions; Spectrum of Operations, Planning Level, and Level of Support. This figure represents a snapshot in time with any particular Phase of the Operation held constant in order to

provide a three-dimensional depiction of the problem space. This is necessary due to the four dimensional structure of the problem for Level I. As the figure shows, excluding the four possible phases, there are still 26 separate operations in the Full Spectrum of Operations, three Levels of Planning, and six Levels of Support. Accordingly, all four major dimensions, when subcategorized, yield a total of 1,872 unique combinations which is the Logistics Requirements Problem Space. This particularization of the logistics requirements space can achieve even more granularity when further subcategorization is imposed on the major dimensions. Past modeling and simulation efforts focused on a very narrow portion of the Logistics Requirements Problem Space.
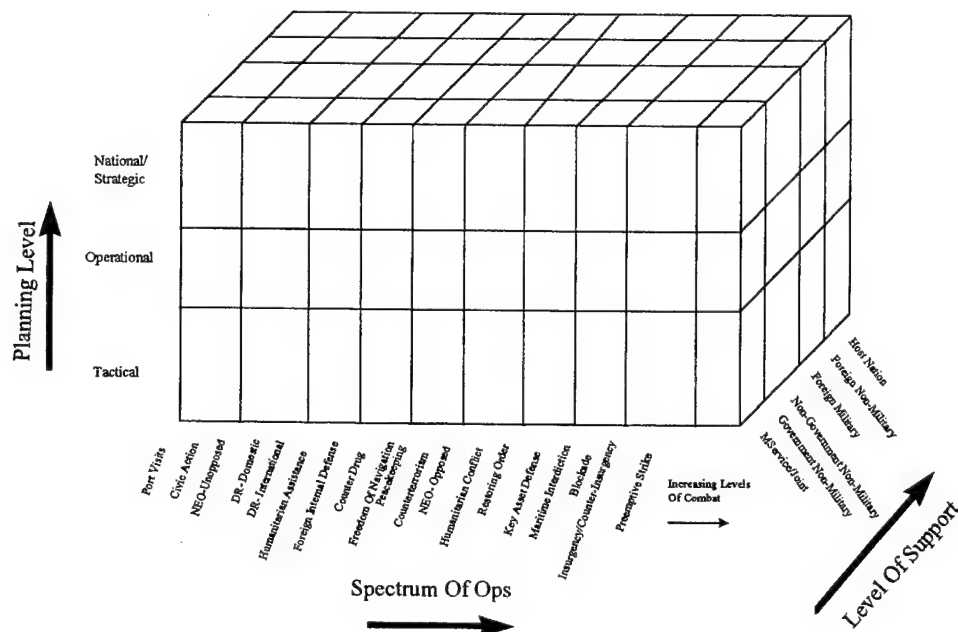
Figure 1. Logistics Requirements Problem Space with Phase Held Constant

Traditional combat models have been concerned with the rightmost portion of the Spectrum of Operations axis where conflict exists and operations tend to be non-

permissive. Most analytic modeling focuses on the National/Strategic Level with only a few concentrating on the Operational or Tactical Levels. To provide individual training at the tactical level, training simulations require high resolution. If the requirements of both the training and analysis communities are to be addressed, a variable resolution model or simulation which encompasses all three planning levels is necessary. The focus along the Level of Support is the narrowest in military efforts; that is, the focus is primarily on the U.S. military region. Only recently has interest peaked in the interactions between the various agencies.

As Figure 1 shows, there are several individual cells defined by the three dimensions; Planning Level, Level of Support, and Spectrum of Operations; with Phase of the Operation held constant. The manifest problem from the logistics requirements perspective is to determine which of the subordinate levels of each of these dimensions should be modeled. It is also necessary to look within each of these cells and develop a methodology to define the logistics requirements due to other environmental or Level II Factors in each. Some of these factors are highly volatile such as population, temperature, and the length of the operation. This thesis is intended to be the starting point in that effort.

II. PURPOSE AND SCOPE

A. PURPOSE

The purpose of this thesis is to evaluate a proposed methodology that measures the need for a logistics representation for selected types of Full Spectrum Operations as its subordinate classes intersect with those of the other three primary logistics dimensions; Phase of the Operation, Level of Planning, and Level of Support. NATO and others are developing standard logistics packages needed to support an OOTW; but, there has not been an effort to quantify or prioritize supplies, transportation, services, or other materials entering a region during an operation. The goal is then to apply the results of the evaluation to further define logistics requirements and determine the level of resolution models and simulations should use for logistics items associated with a particular operation in the spectrum. By establishing priorities for logistics items or functions, the priorities can be used to manage or possibly reduce the number of variables entering a model or simulation. By only representing the appropriate items at the proper level of resolution, the computational demands associated with combat models and simulations may be reduced.

B. SCOPE

A survey designed to collect relevant information from logistics professionals at all levels and in all possible organizations was considered, but attempting to define each of the cells in the Logistics Requirements Problem Space of Figure 1 was beyond the scope of this study. Accordingly, the present study's scope was narrowed to a "proof of concept" demonstration. Figure 2 shows the logistics dimensions used in this study. Unquestionably, the number of individual cells requiring definition is still large, but the

original matrix's 1,872 cells were reduced to 108 evaluation cells and the survey specifically focuses on those cells.

1. Spectrum of Operations

The first goal was to examine only those operations considered Peace Operations and defined by MORS as OOTW. The range of operations was further narrowed by choosing three operations within the OOTW category that were amenable to comparison using survey methodology.
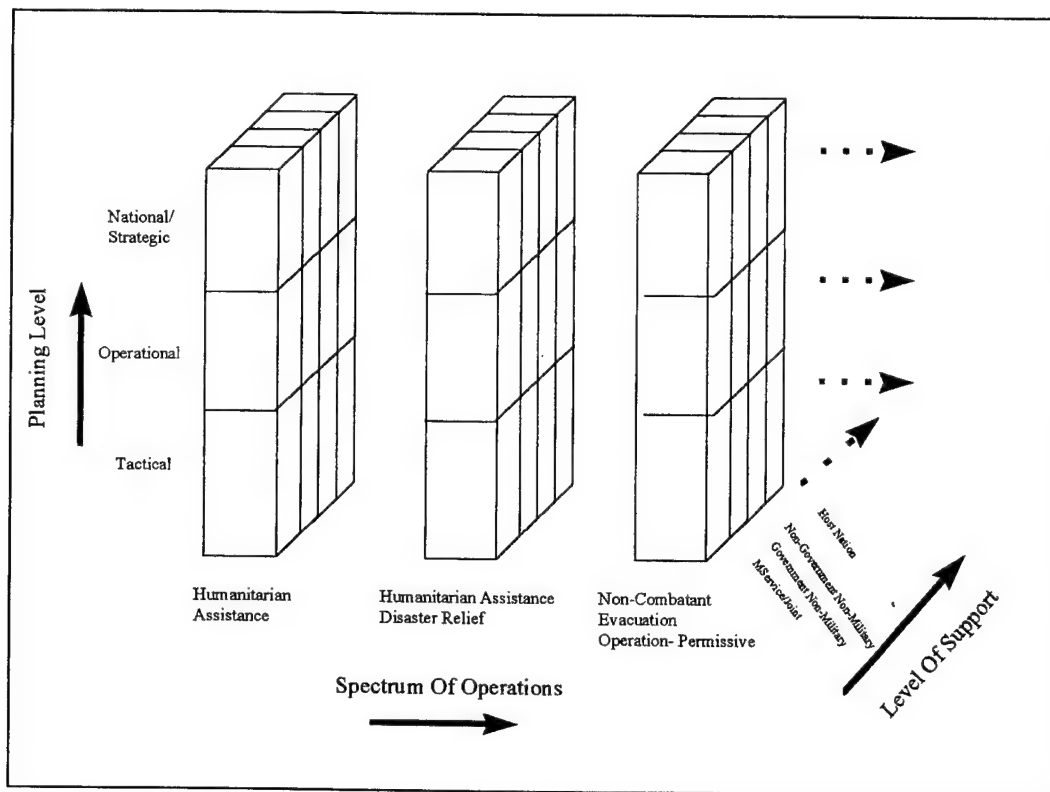
Figure 2. Reduced Scope of Logistics Requirements with Phase Held Constant

2. Level of Support

Two Level of Support subcategories were purposefully excluded: Foreign Military and Host Nation. Trying to find and properly survey logistics personnel in foreign militaries would be very difficult for two reasons. First, the language barrier would

require translations of the survey instrument itself. Second, the "standard items" used by the survey would have to be explained in detail because not all militaries use the same equipment or terminology for various supplies and services. Excluding international logisticians from the sample was consistent with the preliminary nature of this work. "Host Nation" was excluded because any region of the world is susceptible to an OOTW. Moreover, the amount of Host Nation support available is heavily dependent on infrastructure. The assumption made here is that the extent to which Host Nation support can be relied upon would be captured by the respondent's experience. Much of the information for participating organizations in OOTW came from Operation Safeguard '97. [Ref. 12]

3. Phase of the Operation

The phases of an operation have been doctrinally determined for both planning and execution of the operation. However, logistics requirements cannot be explicitly segregated at a particular time or between operational phases. The logistics requirements in the planning, predeployment, and mobilization during Phase I are often the same or similar requirements necessary for the deployment and surge during Phase II. In actuality, they are normally the same supplies and services which need to be moved from their original location to the area of operations. Therefore, it was reasonable to reduce the number of categories in each survey by collapsing over phases which require the same logistics supplies and services. The result was the combination of Phase I and II as a single category.

4. Logistics Functions

Only the supply and transportation logistics functions were included because the most useful information produced would derive from a direct comparison of specific items across those operations. Specific items related to medical, engineering, and maintenance were included when they were part of a standard military supply class; for example, personnel issues or mortuary affairs were not addressed directly. Because the survey expanded as items within the classes of supply increased, the literature was searched to identify the key items in an OOTW. The primary source used to reduce the number of items was Sullivan's seminal work in determining the planning factors for Humanitarian Operations. [Ref. 13]

5. Environmental, Level II Factors

Finally, because there are an infinite number of factors affecting logistics such as geo-political concerns in the area, terrain in the region, daily weather, and the available infrastructure; a search through additional studies and papers related to OOTW was conducted. The lessons learned from operations such as those in Somalia and Haiti, as well as regular reports provided by the Office of Foreign Disaster Assistance (OFDA) revealed the common factors that would affect missions in all regions. The survey's length was constrained by the number of critical, Level II Factors included. Because the goal was to survey personnel who conduct operations in very different regions, it was

important to find factors insensitive to regional impacts on logistics requirements. Three such factors were obtained:

- Size of the Supported Population,

- Climatic Region of the Operation, and

- Duration of the Operation.

C. SUMMARY

The goal is to provide modeling and simulation with useful information on the prioritization of a subset of logistics for a small group of operations. Once the scope of the problem could be reduced to a manageable level and the key factors in OOTW were identified, an appropriate survey instrument had to be developed and a methodology for conducting the analysis had to be constructed. Because there are a large number of survey techniques and methods by which the data can be analyzed, the next chapter provides the framework for this study.

III. METHODOLOGY

A. EXPERIMENT DESIGN

1. Operation Selection

The scope of the study was constrained by the need to keep the size and length of the survey within practical limits. The original 1872 cells in the Logistics Requirements Problem Space could not have been examined using only one survey instrument; but, the 108 cells of the reduced scope version offered a representative subset of categories within Peace Operations that could be reasonably surveyed. Three subordinate operations of the Full Spectrum of Operations, in a permissive environment were evaluated.

- Humanitarian Assistance Operations,

- Humanitarian Assistance/ Disaster Relief Operations, and

- Non-Combatant Evacuation Operations.

These operations were selected because they do not lie at the extremes of the Full Spectrum of Operations as does say, a Preemptive Strike or a port visit. If an operation closer to open conflict were chosen, it would be difficult to determine how many of the military responses were confounded by the need to first resolve the conflict. Therefore, operations closest to peace operations that have traditionally required assistance from a variety of organizations were the operations chosen for examination in a survey. The definitions of the three operations selected for the survey were taken from the MORS work [Ref. 8] and can be found in the survey description in Appendix A.

2. Item Selection

The items within each class of supply or service were chosen primarily based on a 1995 thesis by LT Donna Sullivan of the Naval Postgraduate School in Monterey, CA. [Ref. 13] Sullivan determined the broad planning factors for items needed in Humanitarian Operations only. Her work expanded the military classes of supplies to include items not previously considered, but necessary to these operations. Sullivan's work is useful because before conducting large scale OOTW, the military had little need to consider medical care or other supplies and services for refugees. The primary objective in traditional military operations has always been the sustainment of healthy, 19-25 year old service members and their cohort units.

The U.S. military uses ten standard classes of supply. A class is composed of items that are similar in purpose or use and contains an unlimited number of individual items. Class 9, which refers to repair parts, was eliminated because these items were not considered critical given the types of missions chosen and the nature of this study. Ultimately, 61 items were listed individually and grouped in the nine standard military classes of supplies and services with an additional class called "Transportation" for the purposes of this survey. The Transportation class consists of military, contracted, and private transportation capabilities. In addition to giving the respondent an idea of what comprises a "class of supply", the 61 items created a range of responses within the class. The 61 items were partitioned into the 10 classes of supplies and services used in this study. The items were then collapsed within each partition to give a general response for

the overall class. Appendix A contains a brief description of the items included in each of

the classes used in each survey.

3. Critical Factors

Figure 3 depicts the important variables in the present study. The selected

operations; Humanitarian Assistance, Humanitarian Assistance/Disaster Relief, and

Noncombatant Evacuation Operations; all require logistics support. This support was

partitioned into 10 logistics classes labeled "Supplies and Services" in the figure. The
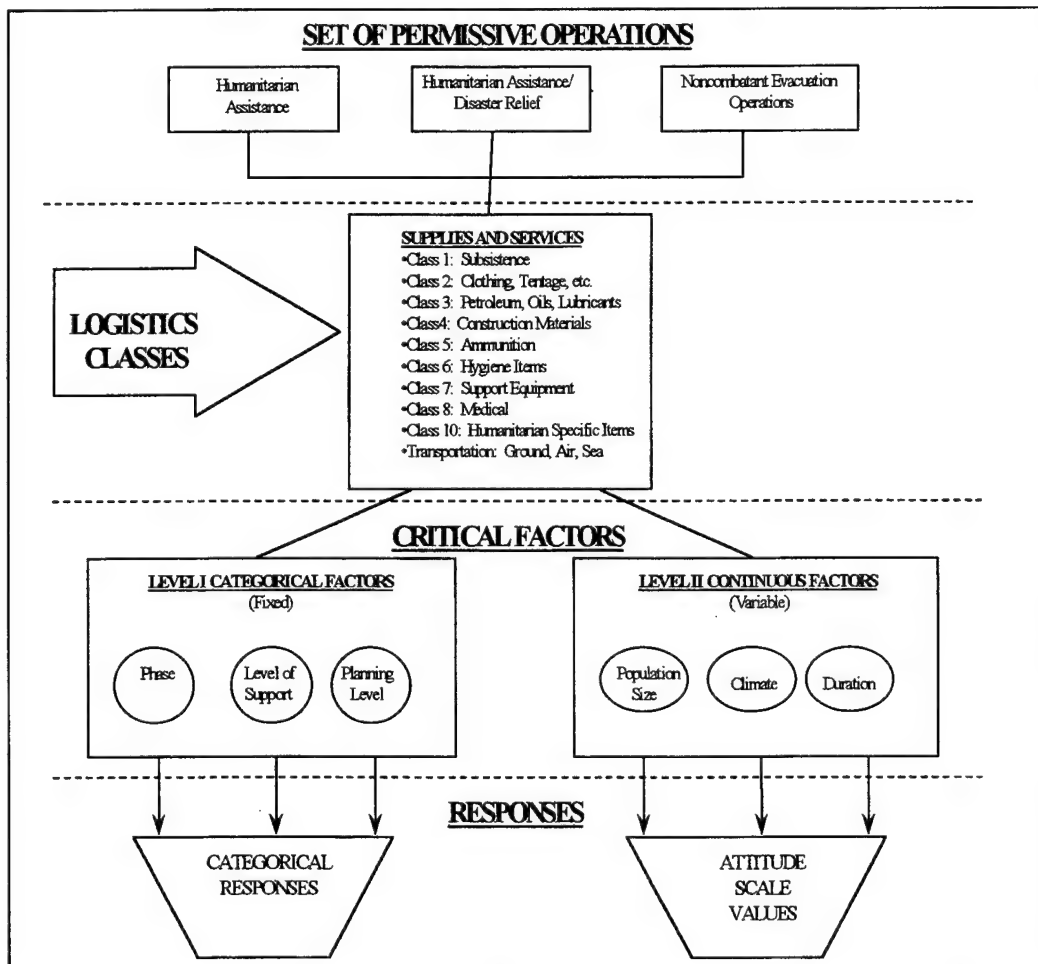
Figure 3. Experiment Variables

study focused specifically on those factors associated with OOTW and split that set of factors into two categories, Level I Categorical and Level II Continuous, as discussed earlier. The Level I set is composed of doctrinal factors that are common and exist to some degree in all operations. The Level II set is composed of environmental factors that vary along some continuous interval, but exist at different levels in operations. For example, at any particular snapshot in time the population size is fixed. However, as the operation proceeds over time, the size of the supported population may increase or decrease based on the OPTEMPO. The Level I and Level II factors lent themselves to separate survey techniques and the responses are utilized differently. The categorical judgments concerning Level I Factors provided response frequencies by category and the attitude scale values concerning Level II Factors resulted in a measure of relative importance for each class of supply or service.

B. QUESTION DEVELOPMENT

1. General

For the three operations addressed in each survey, there was one question for each of the Level I and Level II Factors depicted in Figure 3. The format for the three Level I Factors was a simple categorical judgment response. The format for the three Level II Factors utilized an attitude scale to measure responses. The two formats provided different types of information when the data was reduced. The categorical format provided response frequencies on which to base prioritization of logistics classes, while the attitude scales were used to create a point value which is a measure of the relative importance for a logistics class.

2. Categorical Judgments

The respondent was asked to determine the most applicable category for each of the 61 logistics supplies and services. There were 5 categories of the Level of Support, 3 categories of the Planning Level, and 4 categories of the Phase of the Operation. The respondent was to place one or more "check marks" in the appropriate column or columns corresponding to the Level I category that most applied to the logistics item. The data, when reduced, provided response frequencies of each Level I category for each of the classes of supplies or services. The questions in the categorical judgment format attempt to elicit responses to determine at which level of support, planning, or phase logistics supplies and services would be required or best represented.

a. Phases of the Operation

This question broke logistics support into "phases of an operation" to identify in which phase of the operation it was most important to have a supply or service in theater. This question was intended to provide responses to assist modeling and simulation of OOTW by determining which items should be included in a model based on which phase of the operation is being simulated or modeled. The categories were:

- Phase I & II: Planning, Pre-Deployment, Mobilization, Deployment and Surge,

- Phase III: Operations and Sustainment,

- Phase IV: Redeployment and Demobilization, and

- Non-essential: Operation could be completed without the item.

The non-essential category was included since some of the supplies and services considered were unnecessary to mission completion. This allowed the respondent to so

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indicate in their responses. Specific timelines were not used because these doctrinal phases have varying lengths from one operation to the next. The phases of planning and support are part of all operations; but, shorter operations are based on a condensed timeline. The question elicits data which when reduced produce response frequencies in each of the phases that can be used to derive weights for prioritization.

b. Level of Planning

The next question in the categorical judgment format concerned the Level of Planning at which an item should be supported. Modeling and simulation of OOTW could be aided through better understanding of logistics command and control requirements. Doctrinally, planners or Joint Boards at either the national, operational, or tactical level are responsible for particular supplies and services, which these responses help determine. The results of this question produce response frequencies that provide insight to the operators' view of what type of planning at the appropriate level is required to support an item.

c. Level of Support

The final Level I Factor, Level of Support, uses the categorical judgment format in order to determine which organization or organizations at different levels could best provide support for each class of supplies and services. The categories were structured in an attempt to include all possible organizations that provide the supplies and services in an OOTW. In addition, the organizations were grouped along common

statutory and functional lines resulting in five distinct categories. Again, these five categories were:

- Military,

- OFDA/FEMA,

- Coalition Forces,

- NGO/PVO, and

- Host Nation.

These response frequencies will prove useful in logistics modeling and simulation by assisting in the creation of possible command and control structures for logistics and prioritization of logistical efforts by different organizations.

3. Attitude Scales

An attitude scale from 1 to 7 was used to measure the relative importance of each of the 61 items in the 10 classes of supplies and services with respect to three categories for each of the three Level II Continuous Factors depicted in Figure 3. The Level II Factors; population size, duration, and climate; were constructed in such a way that each contained three contiguous intervals or categories along their respective scales. The respondent was asked to classify each item on the scale with 1 representing the least important and 7 representing the most important.

The three questions of the attitude scale type were developed to measure the impact of Level II Factors on logistics in OOTW. The MORS research report [Ref. 8], Sullivan's thesis [Ref. 13], and lessons learned [Ref. 5] identified which categories of the Level II Factors to include. All CINCs are interested in developing tools to deal with

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these operations and their requirements as well as the environment in which they are operating may be very different from one Area of Responsibility (AOR) to the next.

After evaluating the scope of the original problem, there was no question that the three categories of each of the three Level II Continuous Factors; population, duration, and climate; was close to the maximum number of these categories that could realistically be queried in a survey of this size. Because there were 61 items requiring responses in each of the attitudinal questions, a respondent would have to complete a total of 183 scale judgments for three categories of each Level II Factor.

a. Population Size

The first question of the attitude scale type addressed the size of the supported population. The question was included to determine how the priorities of items would change with respect to the number of people, both refugees and troops, involved in an operation. It is obvious from past operations that logistics are greatly affected by different population sizes. The size of the support force itself must grow as the number of people affected by a disaster or humanitarian crisis grows. The respondent was asked to judge the importance of each item for each of the following intervals of population size:

- Less than 1,000 people,
- 1,000 to 10,000 people, and
- Greater than 10,000 people.

b. Climate

The next question evaluated the impact of climate on logistics in the operation and shows how modeling and simulation needs vary from one climatic region to the next. CINCs are expected to participate in OOTW in a wide variety of geographic locations and currently possess little quantitative information on how those locations impact logistics requirements. The results from this part of the survey can assist planners' and logisticians' understanding of the effect various climatic regions have on logistics. The three categories of climate evaluated were:

- Tropical,

- Moderate, and

- Cold.

c. Duration

The final factor addressed in the survey was the duration of the operation. The length of an operation clearly affects the logistics necessary to complete it. The challenge is to measure the impact even slight changes in time may have on particular classes of supplies and services. Often, a CINC only knows the expected duration of an operation or phase and plans accordingly. When the operation is extended, as with the operation in Bosnia, it is important to know the impact the extension will have on logistics requirements. Because this is a time related question, it is also crucial for modeling an OOTW. If an analyst is interested in what occurs after some time in the operation, the

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model must accurately reflect the logistics requirements over that period. The duration was partitioned into the following intervals:

- Operations less than 60 days,

- Operations between 61 and 180 days, and

- Operations greater than 180 days.

C. USE OF CATEGORICAL JUDGMENTS AND ATTITUDE SCALES

1. General

The two question formats, categorical and attitudinal, allow measurement of deeper structures within the intersections of the three primary Level I dimensions; the Level of Planning, Level of Support, and Phase for a selected type of operation. The study fixed the operation in each survey and then elicited responses for each of the 61 items with respect to the Level I and Level II Factors. The responses for individual supplies and services were gathered in their common classes of supplies and services to create a single response value relative to the Level I and Level II Factors for each of the ten classes.

2. Level I Categorical Factor Use

The concept of collecting the responses for the Level I Categorical Factors is depicted in Figure 4. Fixing the Full Spectrum of Operations axis for a particular operation now allows expansion of the time axis depicted in Phases of the Operation. One of these figures exists for each of the three operations addressed in the survey. The figure is similar to a single column in the reduced scope Logistics Requirements Problem Space from Chapter II, but expanded along the fourth axis. The bars along each axis in the

figure illustrate the response frequencies for a single class of supply or service by category.

For this example, the *Tactical Level* category of **Planning Level**, the *Phase III* category

of **Phase of the Operation**, and the *NGO/PVO* category of the **Level of Support**

received the highest frequency of responses, indicating that these are probably the most

appropriate levels for modeling this example logistics class.
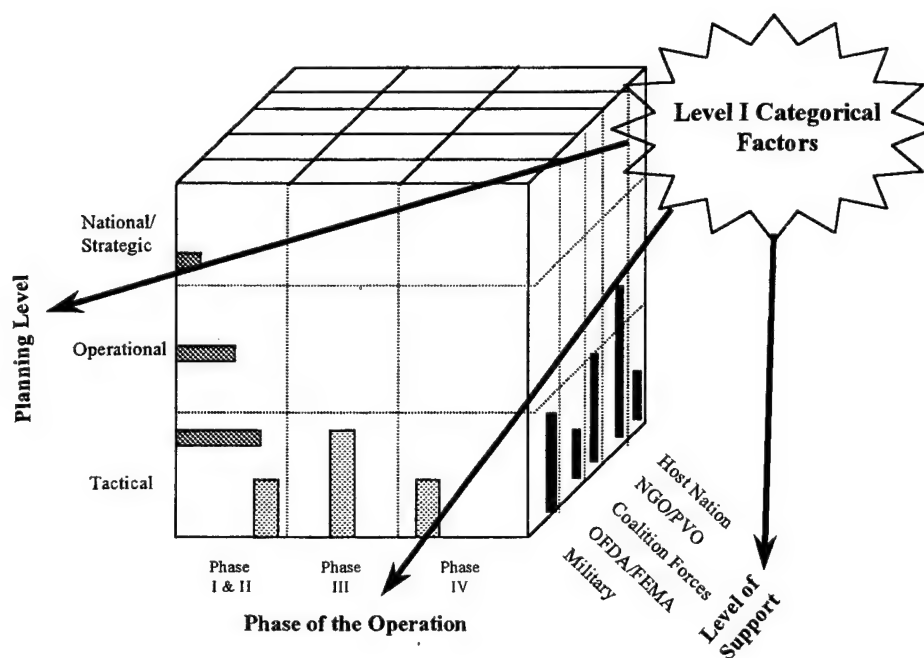
Figure 4. Illustration of Level I Categorical Factor Use for an Operation

3. Level II Continuous Factor Use

The concept of collecting the attitude scale responses for the Level II Continuous

Factors; Population Size, Duration, and Climate; is depicted in Figure 5. An identical figure

exists for each of the three operations addressed in the survey. The scale values for each

class of supply or service by Level II Factor were combined to create a vector for each

logistics class in the space illustrated by the shaded region in Figure 5. For each of the 27 intersections of Level II Factors associated with a particular operation there is a unique set of 10 vectors, one for each of the logistics classes. The Level II Factor data was further reduced and analysis of the sensitivity of these logistics classes to the individual factors is discussed later in Chapter III. D. Analytic Approach.
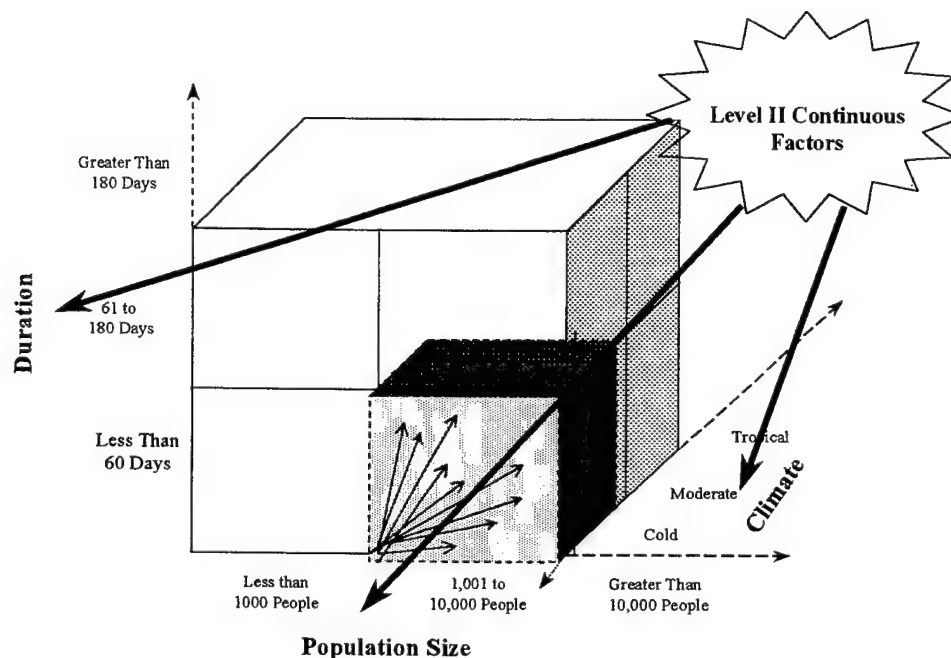
Figure 5. Illustration of Level II Continuous Factor Use for an Operation

D. ANALYTIC APPROACH

1. Choosing the Sample

On July 1, 1997, 260 surveys were mailed to various individuals and organizations that frequently deal with OOTW. Included was a cover letter encouraging participants to return completed surveys by the first week of August 1997. The sample was developed by

using the point of contact lists from OOTW conferences held in the previous 18 months

and attended by faculty at the Naval Postgraduate School. In addition to these lists,

several surveys went to the logistics departments in all branches of all Services and the

Joint Staff. Some of the NGO/PVO participants were found as a result of literature and

internet searches. The expected return was less than 30 percent for military organizations

and less than 20 percent for civilian organizations. During the week of August 4, 1997

phone calls were made as a reminder to those organizations that had not yet responded.

On August 20, 1997, it was necessary to stop recording the responses and begin the

analysis.

2. Chi Square Test

The first goal of the analysis was to show that the Level I and Level II Factors

within an operation have an impact on the respondents' attitudes and therefore the

logistics priorities. In other words, was there a systematic change in the response variable

as this independent variable changed?

The three questions regarding the Level I Factors were set aside and the goal was

to show that this change occurred in the three questions regarding the Level II Factors

using the attitude scale values. A Chi Square Test for Differences in Probabilities was

conducted to determine if responses differed as a function of the factor subcategory. For

example, did changing duration, climate, and population size each elicit different

responses? Table 1 shows the design of a contingency table. [Ref. 14] The rows

represent the change from one subcategory of a Level II Factor to the next. For example,

if the test was conducted on factor A, say *population size*, the first row would contain

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responses for a population *less than 1,000 people*, the second row would contain

responses for a population *between 1,001 and 10,000 people*, and the third row would

contain responses for a population *greater than 10,000 people*. The columns represent

the responses, where 1 indicated an item that was least important and 7 represented an

item that was most important. The $O_{(i,j)}$'s represent the number of observations recorded

in each of the cells from the survey.

	Least Important		SCALE OF IMPORTANCE				Most Important
	1	2	3	4	5	6	7
Factor A Subcategory 1	O(1,1)	O(1,2)	O(1,3)	O(1,4)	O(1,5)	O(1,6)	O(1,7)
Factor A Subcategory 2	O(2,1)	O(2,2)	O(2,3)	O(2,4)	O(2,5)	O(2,6)	O(2,7)
Factor A Subcategory 3	O(3,1)	O(3,2)	O(3,3)	O(3,4)	O(3,5)	O(3,6)	O(3,7)

Table 1. Sample Contingency Table for Chi Square Test

Once these are constructed, a table of expected values must be calculated so that

$E_{(i,j)}$ is the expected value of cell (i,j).

The formula for these expectations is

$$E_{(i,j)} = \frac{n_i \ C_j}{N}$$

where n_i = the sum of the observations in row i

C_j = the sum of the observations in column j

N = the sum of the n_i's or C_j's

Having the observations and expectations available it was now possible to test the null hypothesis

H_0: All of the probabilities in the same column are equal to each other

and the alternative that

H_1: At least two of the probabilities in the same column are not equal to each other. The test statistic, T is calculated as

$$T = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{i,j} - E_{i,j}\right)^2}{E_{i,j}}$$

where r = the total number of rows being compared

c = the total number of columns being compared

A p-value is obtained by comparing this test statistic with the Chi Square values for $(r-1)(c-1)$ degrees of freedom. In all cases in this survey, there were 12 degrees of freedom and α was set at .05. Rejecting the null hypothesis would not explain where the exact differences were, only that differences existed. Once it could be shown that there were differences in responses collapsed across all items, another Chi Square test was used to compare the responses within the individual 10 classes of supplies or services to determine if the responses for each class were different. The classes of supply or services were not broken down further into individual items as there were insufficient cell magnitudes to conduct a Chi Square test. [Ref. 15] Although a Fisher Test could have been used for smaller cell magnitudes, the concept proof did not require this additional breakdown for the analysis. One possible use of a further breakdown of the supply classes and services into individual items would be for refinement of future surveys.

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3. Scale Values

If the differences could be established with the Chi Square Test, it was then possible to begin prioritization of the logistics classes. The scaling literature revealed that while there are several methods of creating a weighting or scale value for survey items, the Method of Equal Appearing Intervals (MEAI) appeared to best suit the needs of this study. Because there were 61 individual items listed in the survey, a Paired-Comparison Method was not practical for this application. Although it is a simple, accurate method of creating scale values, it would require the respondent to make 1830 comparative judgments. [Ref. 16] The Method of Successive Intervals was an option; but, because the scale values would be used in combination, it was necessary for the intervals of the scale values to all be of the same length. Interpreting scale values is not simple to begin with. A combination of these values on different length intervals becomes extremely difficult to analyze and the confidence in the results would be low.

Once MEAI was chosen, just as Thurstone and Chave originally did, only the two extreme values and the middle value of the 1 to 7 scale were defined in the survey. [Ref. 16] The respondent was asked to place each item on this scale by placing an appropriate number from the scale on the survey. The frequencies, proportions, and cumulative proportions were then used to create the scale values

$$S = l + \left(\frac{.50 - \sum p_b}{p_w} \right) i$$

where S = the median or scale value of the statement

l = the lower limit of the interval in which the median falls

$\sum p_b$ = the sum of the proportions below the interval in which the median falls

i = the width of the interval and is assumed to be 1.0

Once the scale values could be calculated, there was a scale value for each logistics class corresponding to each of the critical factors, as in

$$\{ S_{L,P} \quad S_{L,C} \quad S_{L,D} \}$$

where L = logistics class (ie., 1,...,10)

P = population Size (ie., <1,000 people, 1,001-10,000 people, and >10,000

people)

C = climate type (ie., Tropical, Moderate, and Cold)

D = duration (ie., <60 days, 61-180 days, and >180 days)

Therefore, within an operation, each logistics class had nine scale values generated, one

for each of the subcategories within the three critical factors.

4. Interquartile Ranges

Following the calculation of all scale values, the value of the 25th and 75th centiles were calculated much the same way

$$C_{25} = l + \left(\frac{.25 - \sum p_b}{p_w} \right) i \qquad C_{75} = l + \left(\frac{.75 - \sum p_b}{p_w} \right) i$$

where $C_{25}(C_{75})$ = the 25th(75th) centile

      l = the lower limit of the interval in which the 25th(75th) centile falls

      $\sum p_b$ = the sum of the proportions below the interval in which the 25th(75th)

           centile falls

      p_w = the proportion within the interval in which the 25th(75th) centile falls

      i = the width of the interval and is assumed to be equal to 1.0

From this point, the interquartile range, Q, can be determined and is equal to the difference between C_{75} and C_{25}. Therefore,

$$Q = C_{75} - C_{25}$$

In MEAI, this interquartile range provides a way of measuring the middle fifty percent of the observations and a means of determining whether there was either a great difference in the survey responses or possibly some ambiguity in the question. The analysis allows a modeler to use these scale values as one method of prioritizing the logistics classes measured. These scale values were generated for each of the operations to show that although the Chi Square Test indicated differences in responses from one operation to the next, the scale values would also change for a particular logistics class.

5. Creating Vectors from Scale Values

With all of the individual scale values now available, it was possible to determine which logistics class carried the most relative importance with respect to the Level II Continuous Factors; Population size, Climate, and Duration. However, to understand how a combination of population size, climate, and duration influenced the overall importance of a logistics class, it was necessary to define some multi-dimensional relationship of these scale values. For example, a logistics class in a scenario supporting *less than 1000 people* in a *tropical climate* for *less than 60 days* would be represented by a set of three scale values, $\{ S_{L,<1000} / S_{L, Tropical} / S_{L, <60} \}$ that would be quite different from those for another scenario. There are 27 possible scenarios created by the intersection of the three categories for each of the Level II Factors in each operation. Although these values can help elucidate the attitudes regarding a particular factor within a particular scenario, their worth to modeling and simulation is questionable because it is impossible to truly determine how this set of values compares with those of another operation scenario or class of supply.

Therefore, it was necessary to further reduce the data by creating a vector composed of the scale values associated with the dimensions of duration, climate, and population size for the scenario being examined. For each of the scenarios, this resulted in 10 vectors in the Euclidean space, where the X, Y, and Z axis represented importance attributed to Population Size, Climate, and Duration respectively. The relative importance of a logistics class could then be viewed as the magnitude of its vector. As an example,

the magnitudes for a scenario involving more than 10,000 people in a moderate climate for 61 to 180 days would be

$$M_{L,P,C,D} = \sqrt{S^2_{L,P} + S^2_{L,C} + S^2_{L,D}}$$

where, for this scenario, L = logistics class $(1,...,10)$

P = population >10,000 people

C = Moderate climate

D = 61-180 days duration

While these magnitudes no longer represent true MEAI scale values and the individual dimensions may not be truly orthogonal, they provide useful information for modeling and simulation. Some combination of the critical factors will always exist in an OOTW and these magnitudes can be used to represent the overall effect of the combined factors on logistics. The scale values themselves provide the explanation of how each factor contributes individually to the magnitude.

IV. THE EXPERIMENT AND ANALYSIS

A. THE SURVEY PROCESS

In the first week of July 1997, 260 surveys were mailed to military and civilian organizations alike. Most were sent to an individual known to be involved in logistics and the remainder were addressed to the "Logistics or Supply Professional." Of these, 36 organizations responded prior to the cutoff date of August 21, 1997. Some returned incomplete surveys with comments that will be summarized in the recommendations and the rest explained why their organization could not contribute to the study. Ultimately, the data from 16 complete surveys and 4 partial responses were used for the analysis. Of the respondents, 87% were military personnel or civilians representing a military organization. The military personnel represented all of the services and responses from CINC's were received from USCINCPAC, USEUCOM, and USTRANSCOM. Of the respondents, 75% reported that they were professional logisticians in their organizations. A wide variety of experience in OOTW was also reported. The wide geographic response and deep experience level of the respondents provided some guarantee that this was a small, but representative sample.

Of the surveys received, the lowest response rate for a question was 93% of 3600 possible survey data points regarding the relative importance of items for the three categories of Population Size. The missing responses may be attributed to the fact that two of the surveys received had responses for only a few items. The intention of the respondents in these cases was unclear. They may have been to indicate that there was no change in the relative importance from a previous item, which others indicated with a line

from one column on the survey to the next. However, since the intentions of the respondents in these cases were unclear; they could not be recorded. The majority of the remaining blanks were the result of a lack of knowledge or understanding of the item or question on the respondent's part as noted in the comments returned with the surveys.

B. ANALYSIS OF RESPONSES

1. Level I Categorical Factor Responses

a. Phases of the Operation

The question required the respondent to indicate during which phase of the operation an item was most needed. Conducting a Chi Square Test for differences in probabilities indicated that the distributions for Humanitarian Assistance and Humanitarian Assistance/Disaster Relief missions were the same. For the majority of the 10 logistics classes, the *Phase I and II* category received the largest proportion of responses. However, Class 6 (Hygiene) , Class 8 (Medical), and Class 10 (Humanitarian Specific) had higher proportions of responses in *Phase III*, the sustainment phase. This would indicate that respondents had a desire to establish the force prior to concerning themselves with items that would only be needed once sustainment operations began.

For the NEO, it was not surprising to find a larger number of items recorded as non-essential. The generally short duration, low-intensity nature of this type of operation naturally requires a shorter logistics tail. The emphasis is on items needed to support military forces rather than items needed to save a starving population or to repair damaged facilities after a natural disaster. It was clear that Class 10 was not essential to a NEO and Class 6 was considered unimportant with 33% of the responses in the non-essential block.

Ultimately, it was difficult to draw conclusions based on this information other than to conclude that as the operations change, the required items change. The close correlation of the HA and HA/DR missions also indicates that it would be possible to combine these missions when the goal is to determine on which phase of the operation to concentrate with respect to a particular item. Figure 6 depicts a good example of how these responses changed from HA and HA/DR to NEO. The illustration makes it clear that the relative importance of a logistics class with respect to the phase of the operation varies from one
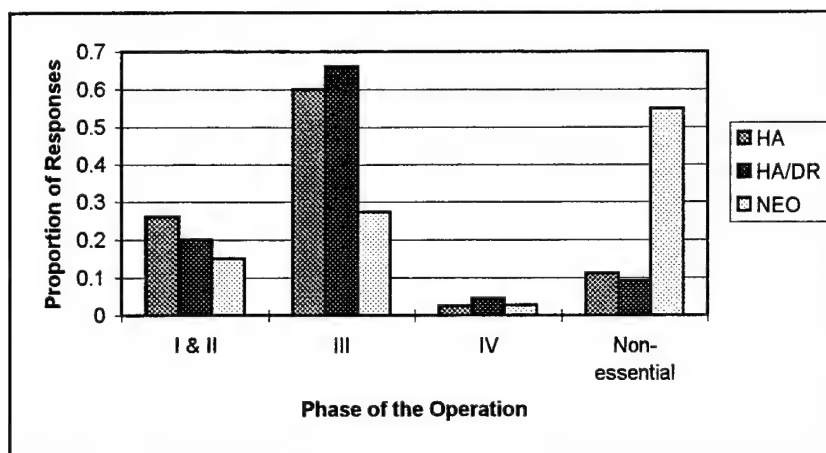
Figure 6. Proportion of Responses by Phase for Class 10 Items

type of operation to the next. Models and simulations could use the proportions of responses as a way to reduce the number of computations required. If this survey is truly representative of a logistician's attitudes regarding in which phase of the operation an item is needed, then only items with a high proportion of responses need to be concentrated on in the model or simulation. A complete set of the charts for this question are available in Appendix B.

b. Level of Planning

The respondents were asked to put a check in at least one of the three categories in the Level of Planning. The Planning Levels, previously described, were used directly and the response frequencies offered a visual inspection of the respondents' attitudes on the level at which they believe items are most appropriately planned for or controlled. There were no apparent differences between the planning level indicated for a logistics class from one operation to the next. This would indicate that although the operations may be dissimilar, the planning level for logistics classes is independent of the operation type. The responses for most classes indicated that the appropriate planning level was the tactical level. The exceptions to this were Class 6, Class 7, Class 8, and Class 10. The responses for these classes indicated that the operational level was more appropriate. These results would be useful in providing planners at those levels with an idea of how cognizant they must be of particular logistics classes. Figure 6 provides an illustration of the close relationships of the planning level across the operations. A complete set of bar charts is contained in Appendix C. Figure 7 indicates that the appropriate level of planning is the tactical level for class 2 materials and that this priority does not change based on the operation of interest to the planner. This is not only important to the planner; but, modeling and simulation efforts must understand that this level is independent of the operation in the design of command and control in a system. The idea that the planning level is highly predictable and deterministic as opposed to stochastic is valuable knowledge for logisticians as well as application in models and simulations.
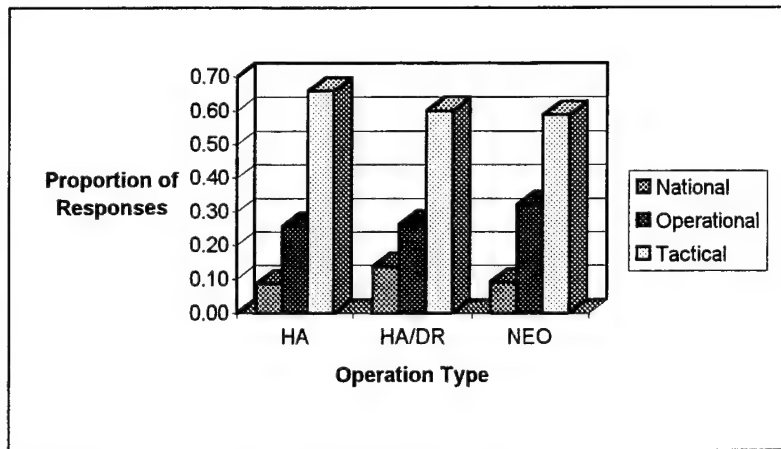
Figure 7. Proportion of Responses for Class 2 Items by Planning Level

c. *Level of Support*

The final categorical question asked the respondents to again check appropriate blocks to indicate which of the listed organizations could best provide for the 61 logistics items. Small insights were gained as to how organizations could be expected to provide for the type of operations listed. It appears that there is no difference in the level of support appropriate for a logistics class across different operations. The most useful information comes from the respondents indications of which organization could best provide for the item in question. The logistics classes exhibiting clear differences in which organizations should be tasked to support them in HA operations are included in Figure 8. These response frequencies would provide useful information when a NATO-type Role Specialization structure was being used. When the commander is attempting to determine who can best provide for the item in question, it would only be necessary to look at the list of participating organizations and the results of this survey to determine who should be assigned the responsibility. For models and simulations, the same concept would apply.
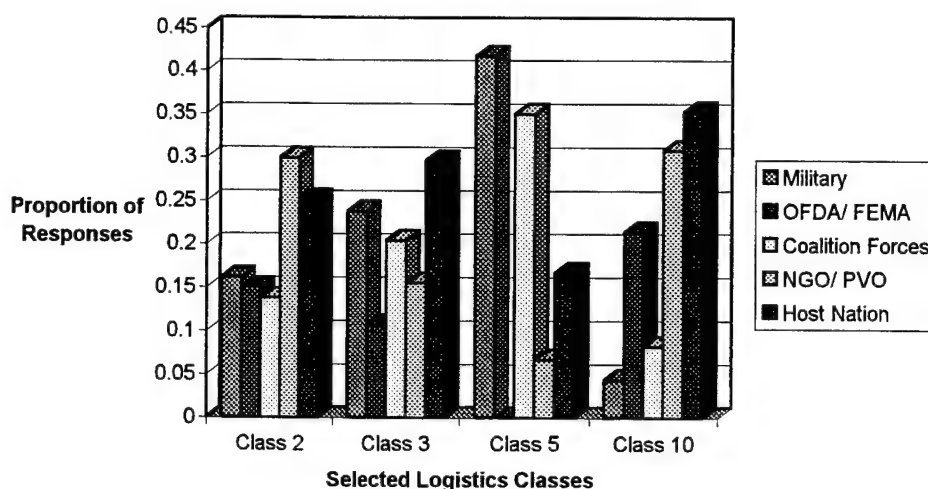
Figure 8. Proportion of Responses for Selected Logistics Classes in HA Operations

As models and simulations attempt to incorporate entities other than military

forces, it is not only important to understand what resources they have brought with them,

but how these organizations can best be utilized. It is clear from Figure 8 that the

commander in a real-world operation and the mathematician developing a logistics model

would be served best by having OFDA/FEMA, NGO/PVO's, and the Host Nation provide

Class 10 items when possible. In reality, there are many other factors, such as political

considerations, driving the provider of the items. However, it is important to understand

where to look first when planning support for an operation. In a real-world operation, this

means avoiding duplication of effort by organizations working toward the same end, but

not necessarily under the same command structure. In models and simulations, this is the

type of information that improves the ability to represent the entities involved. The

complete set of response frequencies for this question is included in Appendix D.

2. Level II Continuous Factor Responses

a. Population Size

This question asked the respondent to indicate the relative importance on a scale of 1 to 7 for each of the logistics items listed relative to the size of the population that was being supported in the operation. The population sizes were presented in three categories; less than 1,000 people, 1,001 to 10,000 people, and more than 10,000 people. Through literature searches related to Peace Operations, these breakdowns seemed natural for historical operations. The Chi Square test statistics indicated that the null hypothesis could be rejected in all operations with a level of significance of at least .01. Applying the MEAI methods, the scale values for HA were calculated and are presented in Table 2. It is easy to see that there are changes from one population size to the next. The relative level of importance with respect to population size is not the only factor provided. Often, it is more a question of how much more important one class is than another. It can be seen that for a small population, Class 5 has a value of 1.72 while Class 1 has a value of 4.34, reflecting the fact that subsistence is more of a concern than ordnance under this condition. The same calculations were made for NEO and HA/DR operations and the complete results for each of the operations can be found in Appendix E.

Humanitarian Assistance			
Logistics Class	<1K	1-10K	>10K
1	4.34	5.21	5.84
2	4.31	5.08	5.38
3	4.34	5.10	5.76
4	3.74	4.90	5.49
5	1.72	3.50	4.33
6	4.00	4.50	4.72
7	3.88	5.00	5.86
8	3.88	5.25	6.00
10	3.23	4.25	4.89
Transportation	3.00	3.91	5.16

Table 2. MEAI Scale Values for HA Operation over Changing Populations

b. Climate

This question asked the respondent to again use the 1 to 7 scale to indicate the relative importance of the item for three climate descriptions. Again, the Chi Square test rejected the null hypothesis that the responses for each of the climate descriptions was the same. MEAI scale values were calculated and Table 3 contains those values obtained for the HA operation. These again show that changes in the relative importance occur

Humanitarian Assistance			
Logistics Class	Tropical	Moderate	Cold
1	4.30	4.44	4.19
2	3.38	3.78	5.61
3	3.47	4.22	5.53
4	3.76	4.10	5.16
5	3.30	3.59	3.93
6	3.50	3.21	3.10
7	4.95	4.50	4.75
8	4.63	4.33	5.19
10	3.69	3.82	3.75
Transportation	4.02	3.87	3.98

Table 3. MEAI Scale Values for HA Operations over Changing Climate

as the climate in the region changes. However, unlike the scale value changes due to an increasing population, these are not consistently increasing or decreasing. As an example, the scale value of 4.63 for Class 8 in a tropical climate drops to 4.33 in moderate climates and climbs again to 5.19 in a cold climate. This reflects the logistician's attitude toward varying climates accurately because it shows recognition of the fact that an extreme climate has a greater impact on the medical condition of the population. The tables of all scale values can be found in Appendix F. The Appendix also contains the interquartile ranges for each of the classes.

c. Duration

The final scale value question again required the respondent to use the 1 to 7 scale to rate relative importance of items as the duration of the operation changes. Again, Chi Square test statistics rejected the null hypothesis with a level of significance of at least .01. Table 4 summarizes the MEAI scale values obtained for HA operations

Humanitarian Assistance			
Logistics Classes	Less than 60 days	61-180 days	Greater than 180 days
1	4.65	4.95	5.43
2	3.53	4.40	5.18
3	4.00	4.72	5.29
4	3.94	5.10	5.58
5	3.40	3.96	4.17
6	3.28	5.00	5.50
7	4.58	5.79	6.23
8	3.81	5.66	5.91
10	3.25	5.10	5.98
Transportation	3.61	4.31	4.82

Table 4. MEAI Scale Values for HA Operations over Changing Duration

of varying duration. Overall, the results were generally as expected because as duration increased, the scale values also increased. Similar to changing the population, these scale value changes indicate that although a logistic class becomes more important as duration increases, the amount of increase is not the same for all logistics classes. In a short operation, Class 1 items have the highest scale value; but, they quickly drop in rank as the duration increases. The scale values for all three operations can be found in Appendix G.

3. Dimensional Analysis

Although the results of the individual questions provided solid information on how respondents viewed the logistics classes with respect to one factor or another, the goal was to examine how the factors interacted. For the categorical questions, the results were left as response frequencies for the various categories. The potential applications will be discussed later. For the scale value questions, where MEAI scale values were generated, the goal was to provide information on how the interaction affects the relative priorities a logistic planner should use for the logistics classes.

As mentioned, the three factors can be viewed as a point in Euclidean space with the dimensions being Population Size, Climate, and Duration for each of the 27 intersections for an operation. Therefore, it is possible to use the scale values as the coordinates of this point and then to measure the magnitude of a vector from the origin to this point. As an example, the extremes of the HA operation calculations are included in Table 5 where all three factors change from one extreme to the other. In other words, population has gone from small to large, climate has gone from tropical to cold, and duration has gone from short to long within a Humanitarian Assistance Operation. There

is a tremendous amount of information available through making these type of

comparisons between scenarios.

	Scale Values			Magnitude		Scale Values			Magnitude
Logistics Class	Less than 1,000 people	Tropical Climate	Less than 60 days	Distance from the Origin	Logistics Class	Greater than 10,000 people	Cold Climate	Greater than 180 days	Distance from the Origin
1	4.34	4.30	4.65	7.68	1	5.84	4.19	5.43	9.01
2	4.31	3.38	3.53	6.51	2	5.38	5.61	5.18	9.34
3	4.34	3.47	4.00	6.85	3	5.76	5.53	5.29	9.59
4	3.74	3.76	3.94	6.60	4	5.49	5.16	5.58	9.37
5	1.72	3.30	3.40	5.04	5	4.33	3.93	4.17	7.18
6	4.00	3.50	3.28	6.24	6	4.72	3.10	5.50	7.88
7	3.88	4.95	4.58	7.78	7	5.86	4.75	6.23	9.78
8	3.88	4.63	3.81	7.14	8	6.00	5.19	5.91	9.89
10	3.23	3.69	3.25	5.88	10	4.89	3.75	5.98	8.58
Transportation	3.00	4.02	3.61	6.18	Transportation	5.16	3.98	4.82	8.10

Table 5. Calculation of Magnitudes for Two Possible Scenarios in HA Operation

Not only is it clear that the magnitudes have increased over all logistics classes;

but, the scale values explain which of the factors has the greatest impact on the magnitude.

For example, on the left part of Table 5, ordnance has a magnitude of 5.04 while the

population scale value is only 1.72 and the duration scale value is 3.40. Therefore,

ordnance is more sensitive to duration changes in this scenario and a small change in

duration produces a larger magnitude change than does the same small change in

population size. The magnitudes themselves provide very useful information.

Although all logistics classes experience an increase from the scenario on the left in

Table 5 to that on the right, an ordinal ranking reveals that medical resources have gone

from the third most important to the first. The change from one scenario in the operation

to the next could be very useful in determining how to allocate resources when

simultaneous operations are encountered. The ordinal ranking of the data from Table 5 is

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depicted in Table 6. The ranking shows how specific classes increase or decrease in

relative importance as this scenario changes.

Ranks of Logistics Classes by Decreasing Magnitude

Logistics Class	Magnitude	Logistics Class	Magnitude
7	7.78	8	9.89
1	7.68	7	9.78
8	7.14	3	9.59
3	6.85	4	9.37
4	6.60	2	9.34
2	6.51	1	9.01
6	6.24	10	8.58
Transportation	6.18	Transportation	8.10
10	5.88	6	7.88
5	5.04	5	7.18

Table 6. Ordinal Rankings

There are other interesting results that can be displayed in several ways, as in

Figure 9. The figure shows how scale values for logistics classes change in an HA/DR

operation when the population stays small and the climate remains cold but the duration

increases from short to extended. In this case, the relative importance of the logistics
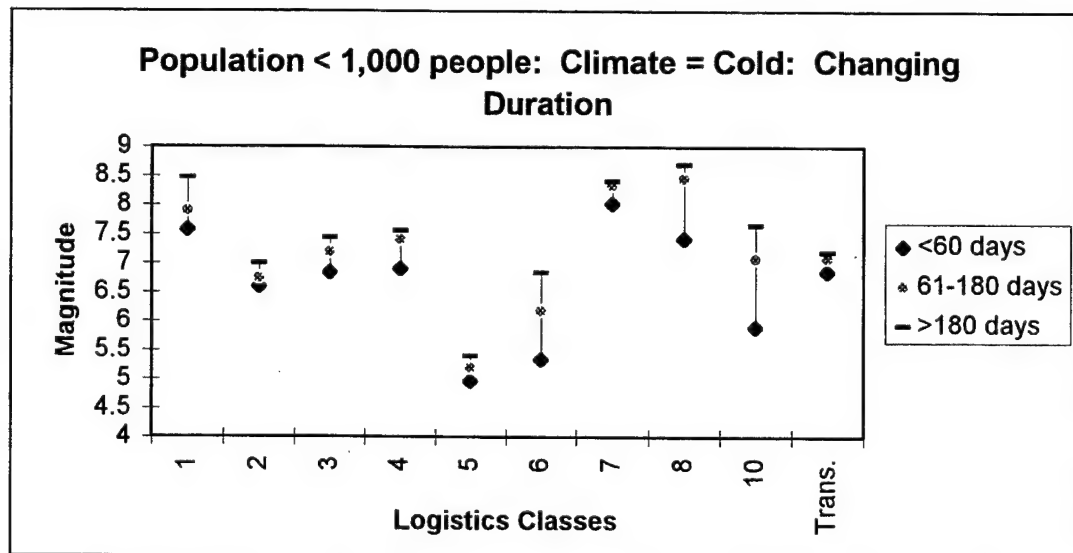
Figure 9. Magnitudes for Logistics Classes in HA/DR Across Changing Duration

classes does not change as radically as in the previous example; but, there are still shifts in the ordinal ranking of the logistics classes. Identifying these relationships is key to effective planning and execution of a logistics oriented operation. Although changes might be small, they still represent a shift in the views of what is most important. It should also be noted that the magnitudes in Figure 9 provide a measure of sensitivity to the changing duration when the population is small and the climate remains cold. Here, Class 6 and Class 10 items exhibit the greatest sensitivity over changing duration since the change in their magnitudes from one duration to the next is the greatest.

C. SENSITIVITY ANALYSIS

Although dimensional analysis is useful for a particular scenario, what is really needed for modeling and simulation is the ability to determine how the Level II Continuous Factors; Duration, Climate, and Population Size; affect the logistics classes across all operations. After examining the 27 possible combinations of the three Level II Factors in each of the three operations, it was possible to explain how sensitive the logistics classes are as these Level II Factors change. Absolute differences in the magnitudes of logistics classes from one of the combinations to the next provides a measure of the sensitivity of that class to the changes that take place.

1. Using Absolute Differences

The goal was to establish a measurement of the sensitivity of a logistics class to each of the changing factors individually. Therefore, when all of the absolute differences were calculated, the sums of those differences over a single factor, such as duration, provided a measure of the sensitivity of a class to that particular factor. This is a unitless

value that means little in isolation; but, when compared to the values calculated for the

other classes, it provides a relative sensitivity measure from one class to the next. The

greater sums of absolute differences indicate that there was a large change in the

magnitude as the factor changed.

Figure 10 provides an example of this sensitivity measurement. Summing the

absolute differences over the changing duration and climate leaves those differences that

can be attributed solely to a change in population size. The information in charts such as

that in Figure 10 actually provide valuable information for modeling and simulation. The

values of the absolute differences should not be confused with the magnitudes and do not

reflect relative importance, but rather reflect which of the classes will experience the

greatest magnitude change as one of the factors changes. What is evident from the values

in Figure 10 is that Class 5, for example, is the most volatile logistics class as the
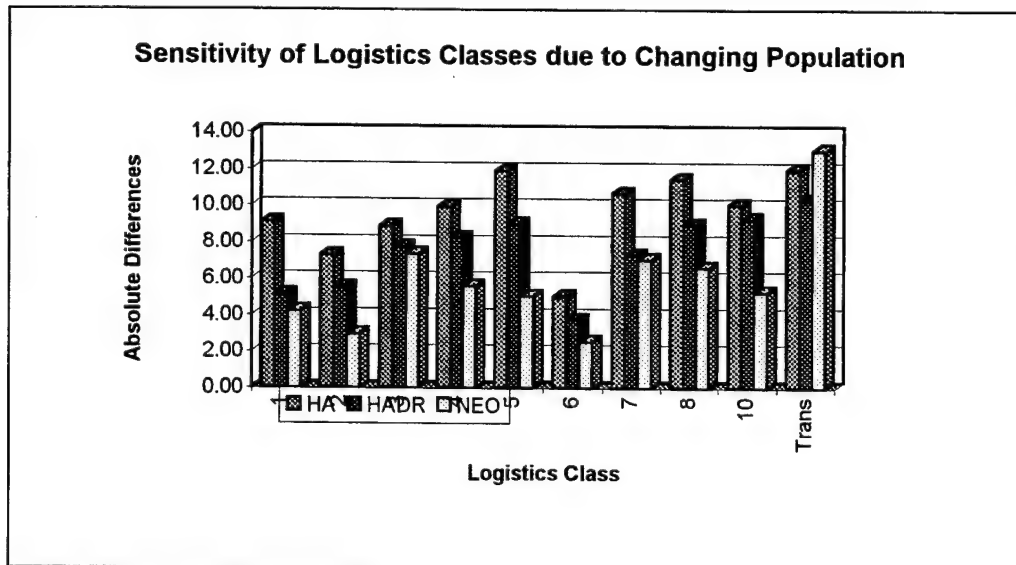
**Figure 10.** Sensitivity Chart for Changing Population

population size changes in a HA operation. So, as the population increases, the attitudes about Class 5 items experience the greatest changes from one population to the next.

This sensitivity of Class 5 items may be explained by operations such as the Humanitarian Assistance mission in Somalia. When gangs were stealing relief supplies, it was clear that security considerations were more important as the effort grew. The larger amount of relief supplies for a larger population might make the logistician put more effort into ordnance for security. Looking at this same class in a NEO, it is interesting to note that Class 5 items are no longer the most sensitive to the changing population. This also makes sense because in a primarily military operation, forces would be expected to have already appropriately armed themselves and the amount of ordnance would not vary much with the population size. Therefore, the attitudes of the logisticians toward the relative importance of this class does not change with a variable population size in a NEO.

Some of this may seem to contradict the earlier example in Table 6 that stated duration would have the greatest impact on Class 5 items. However, in that example, only duration was changed and the value observed is only applicable to a particular operation. This method accounts for the simultaneous change of all three Level II Factors and describes the sensitivity of a logistics class relative to each one of those factors.

For modeling and simulation, this sensitivity value is an extremely useful number. The sensitivity can help determine if it is realistic to model a class deterministically or stochastically. Looking at this value in conjunction with the other measures obtained gives a much clearer picture of the interrelationships between logistics classes across a few operations.

An example of how the overall sensitivity measures can contribute to the understanding of the system is contained in the next two figures. Figure 11 shows the scale values obtained for two different scenarios within an HA/DR. Population size, Duration, and Climate have all been varied and the relative priorities can be seen in the magnitude of the logistics classes. However, the change in the relative priorities cannot be explained by this figure alone. Therefore, by choosing two of the classes, Class 3 and Class 10, whose magnitudes have experienced large changes; the sensitivity due to each of
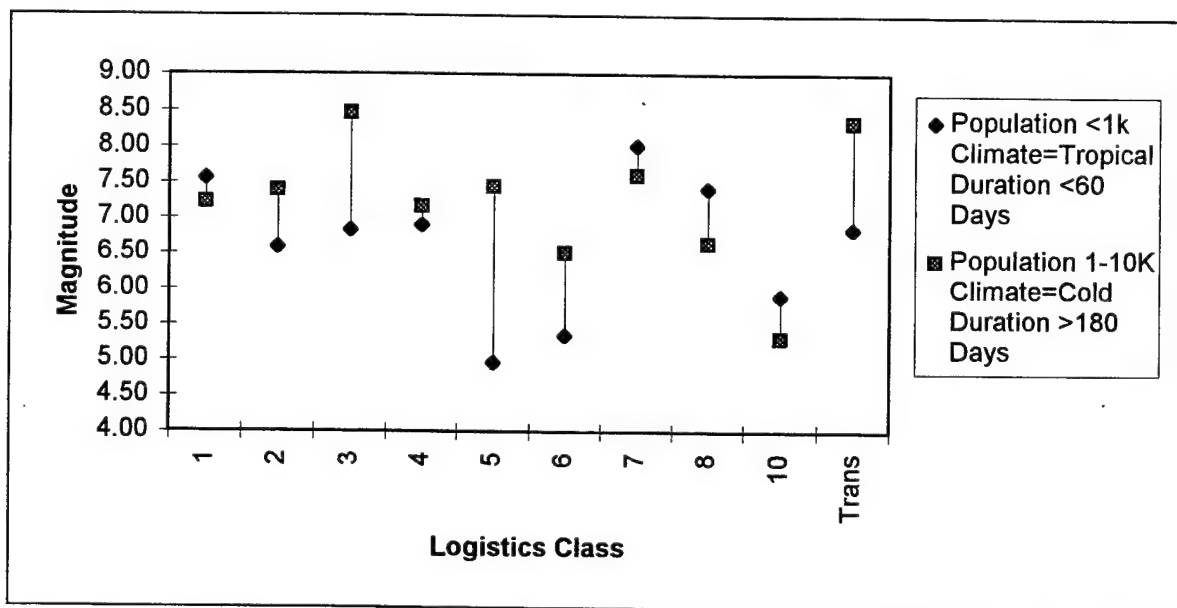
Figure 11. Example of Magnitudes for Two HA/DR scenarios

the factors in an HA/DR operation is displayed in Figure 12. From Figure 12, it is now possible to see that Class 3 is most sensitive to the changing climate. Therefore, the climate change can account for the largest portion of the magnitude change in Figure 11.

Transportation, on the other hand, shows a completely different sensitivity effect. Although the changes in magnitude of Class 3 and Transportation were about the same, Figure 12 shows that Transportation is most sensitive to the changing population and that
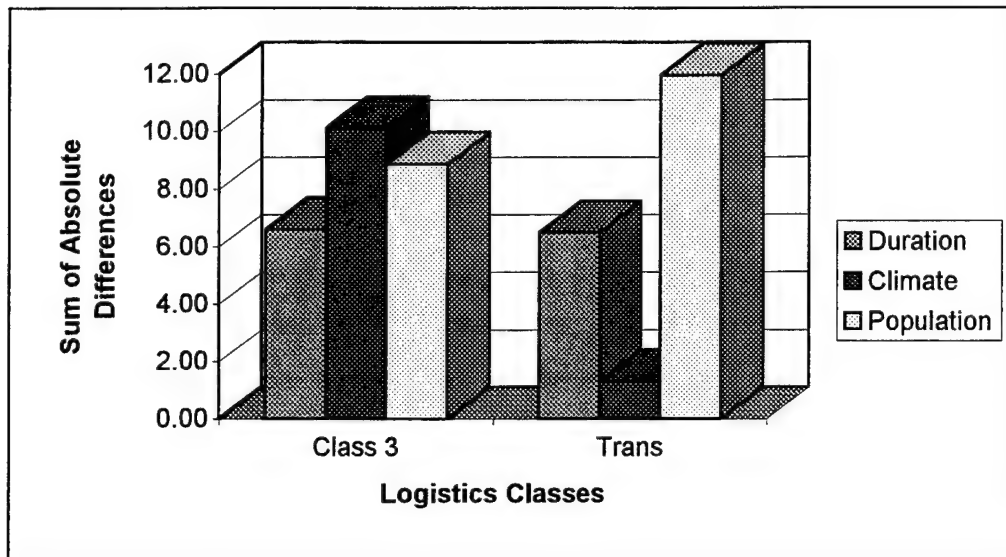
Figure 12. Sensitivity of Selected Logistics classes

the changing climate has the least effect. The sensitivity of logistics classes to the Level II

Factors are contained in Appendix H. These are the types of relationships that will have

to be explained prior to undertaking any logistics related modeling or simulation effort.

V. DISCUSSION

A. SUBSTANTIVE FINDINGS

The data presented thus far make it clear that logistics priorities in any operation differ significantly across both Level I and Level II Factors. This section discusses the implications and uses of this information in logistics modeling and simulation of OOTW. Because modeling and simulation efforts are generally developed for two different purposes, analysis and training; it is necessary to show that the results of this study are applicable to both.

The results would not surprise a professional logistician. Nearly any "operator" working in the field would recognize that as the situation changes, the emphasis on certain logistical requirements also changes. There is a question of how these requirement changes occur and what the scope of a change is. Subsistence items are obviously a primary object of interest in Humanitarian Assistance operations; however, the study reveals that logisticians recognize that some amount of infrastructure is needed to support the distribution of a large amount of subsistence items. The need to establish a logistics infrastructure can outweigh the priority of the need for a supply item itself. For example, the need for security of items was highlighted in Somalia where large amounts of relief supplies were actually stolen by gangs before the supplies could be delivered to the intended population. Security related supplies and services must acquire more attention if the goods are to actually be delivered to their intended destination. There is a trade off: it is necessary to determine at what point the relative importance of security items surpasses the importance of minimal levels of subsistence or vice versa.

The data also revealed a welcomed pattern of consistency. In almost every case, the ordinal ranking of a particular logistics class was either non-increasing or non-decreasing as the duration or population increased. In other words, if a logistics class increased in relative importance as the population grew from less than 1,000 people to greater than 1,000 people, its relative importance did not decrease in importance as the population became greater than 10,000 people. Table 7 illustrates this concept. In the table, Class 10 is ranked ninth when Duration is *Less than 60 Days*. As the Duration increases to *61-180 Days*, Class 10 is ranked eighth in relative importance. Finally, as the Duration is extended beyond *180 Days*, the importance of Class 10 items has increased to sixth.

Duration = <60 days		Duration = 61-180 days		Duration >180 days	
Logistics Class Ranking	Magnitude	Logistics Class Ranking	Magnitude	Logistics Class Ranking	Magnitude
1	7.76	7	8.30	7	8.61
7	7.51	8	8.12	8	8.29
3	7.26	1	7.94	1	8.25
8	6.95	3	7.68	3	8.04
4	6.80	4	7.53	4	7.87
2	6.73	2	7.23	10	7.79
6	6.09	6	7.16	2	7.73
Transportation	6.08	10	7.15	6	7.52
10	5.97	Transportation	6.53	Transportation	6.87
5	5.24	5	5.62	5	5.76
* Population is Less than 1,000 people and Climate is Moderate for all Durations					

Table 7. Illustration of Logistics Class Rankings

These data can be used in a logistics module for any model or simulation whose objective it is to implement logistics over time in some prioritized or logical fashion.

Simulations and most models are based on the effects of actions over time. The response frequencies with regard to the Phase of the Operation could reduce the number of decisions that need to be made in the simulation or model by including only those items considered essential for the current phase being replicated by the simulation or model. If the desire is to include all classes, then a logistics class should be represented at a higher level of fidelity if it has a greater relative importance or priority.

The Level of Planning frequencies could also help solve the problem of resolution in current models. Respondents indicated that there were very few items that warranted National level planning. Because many simulations and models are designed to assist at a particular planning level, only those items with significant response frequencies for that level of planning need be considered or represented with great fidelity. Those levels with the greatest response frequencies would indicate that a unit level breakdown of items might be most appropriate and those with a low proportion of responses would only need to be represented at the lowest level of resolution, usually gross planning factors such as ton-miles or pounds/person/day.

In existing models, this type of information could be used to determine which items have priority over others and should receive special consideration when transportation is constrained and at a premium. Obviously, the actual situation would dictate which items an operator would want in the region; but, if an analysis tool such as the Enhanced Logistics Intratheater Support Tool (ELIST) is used, there is little human involvement once the model is running. If a plan is deemed infeasible, it is necessary to determine what should be included given the available resources and how the included items should be

prioritized. ELIST determines the feasibility of a plan, whether infrastructure will support a plan, whether theater transportation will support CINC required delivery dates, and whether bottlenecks occur. Often, when a plan is determined to be infeasible, the necessary resources are made available until the plan becomes feasible. What is not addressed by ELIST is if the mission absolutely had to be accomplished with the available resources, what would be left behind? The enhancement offered here is the ability to take an infeasible plan and help determine on what to concentrate using a prioritization of the logistics assets. In the case of a transportation problem, a knapsack algorithm might use the magnitudes developed here as the weighting of the items, while available transportation resources would be the knapsack for a particular scenario.

A modular design, like the JTC, could benefit from the inclusion of this survey information in a command and control algorithm. Determining the host and ghosting modules is always an important command and control step in modular model design. The host is the main module that creates and controls an entity in the model, and a ghosting module has the ability to display and possibly control the entity on a limited basis. The response frequencies for Level of Planning, Phase of the Operation, Level of Support could provide the necessary information to ensure support is provided or controlled at the appropriate levels. If the logistics module is a separate model, it could carry all of the pertinent logistics information; but, it would limit the information it distributes according to the survey data.

For example, if a module requests a class of supplies or services, the level of support with the largest response frequency would be queried first to provide the supply

or service. If that level did not exist in the model, the request would be passed down to the next level of support. As an example, if Class 10 items were needed by a commander, Figure 8 in Chapter 4 shows that the host nation should be queried first to see if those items are available because survey respondents indicated that the host nation was best suited to provide support of Class 10. If the Host Nation does not have the requisite Class 10 items, the next step would be to query any NGO's if they are represented in the model. The final source for support of these items would then be the military. In wargames, this could provide a check to ensure the decision maker understands that there are more preferable options. For analysis, the preferences could be used as parameters or coefficients in optimization models to ensure the correct command and control procedures are followed when logistics are implemented. This assumes, of course, that future models and simulations will attempt to incorporate all of the units that play roles in OOTW. In practice, this idea could give the Civil Military Operations Center (CMOC) a decision making tool to determine how requests should be routed.

B. METHODOLOGICAL SHORTFALLS

It is clear that there were too few survey responses. There are two reasons believed to be primarily responsible for this. First, the survey was long. It would take someone who understood logistics between forty-five minutes and one hour to complete the survey. Many of the logisticians who replied stated that they were simply too busy with ongoing operations to participate. Additionally, others that were involved in operations were often overseas and did not get the survey forwarded in time to complete it. Secondly, the survey was not mailed until the first week of July 1997 and respondents

were asked to have their responses mailed by the first week of August. In retrospect, this was too little time for such a lengthy survey. Responses were still coming in at the end of August; but, data collection needed to be stopped in the third week in order to complete the analysis.

The low response rate also made the goal of comparing the attitudes of civilian logisticians and their military counterparts impossible. The initial goal was to accurately describe the differences that might exist in different organizations, particularly the military and relief organizations. However, the goal of constructing stratified samples was not attainable due to the small number of civilian respondents.

The MEAI provides a method for calculating a single scale value; but, the interquartile ranges are also important to note. The interquartile range is used in this study to determine which of the survey questions might have been ambiguous. MEAI produces a single number that was used as the value in calculating magnitudes to show relative priorities. However, if the interquartile range was wide, it is possible that more accurate values could be obtained by clarifying the question or increasing the sample size. This also means that there is a degree of uncertainty as to what the true relationship is when the interquartile ranges of the logistics classes overlap. Additionally, there is no traditional statistical way of analyzing variance when using MEAI. Without some sort of distribution of the responses, it is only possible to say that a logistics class is most appropriately modeled stochastically because of a wide range of scale values or deterministically if the converse is true. Heuristically, the point values provided accurate measurements and

sensitivities for the logistics classes; but, that can be difficult to justify with a low number of responses.

Because the Level II Continuous Factors may or may not actually be combined on orthogonal scales; it would be difficult to develop a response surface over the dimension space and possibly use gradient search methods to explain changes. The method was heuristic in nature; but, it appears that the scale values for changing duration and population size could be fit linearly if desired. A visual inspection of the responses over changing climate would indicate that there is some sort of nonlinear relationship of the importance of the logistics classes to the varying climatic regions. Of course, this means that the vectors are most likely nonlinear and development of a response surface quickly becomes complex. It could be accomplished, but developing a response surface offers little in terms of additional modeling and simulation information and would be extremely difficult to compute and actually implement. To acquire the information necessary for a response surface would also require a much larger survey. Since the length of the survey is already an impediment to data collection, it would not be practical to attempt expansion for the sole purpose of creating this response surface.

C. RECOMMENDATIONS

There are many recommendations relevant to this effort and especially how it might be expanded and improved. Several were developed from comments provided by respondents on the completed surveys. Many of the respondents commented that the survey should be separated, one for military personnel and one for civilian personnel. The classes of supplies and services are specifically military terms and were not clear to all of

the civilians. It would be possible to use two separate surveys to get responses to the same questions. The next recommendation is to reduce the number of logistics items that a respondent is asked to consider. Now that this pilot study has been conducted, those items that received significant non-essential response frequencies, such as Class 10 and Transportation in NEO could be removed from the survey. There is also merit in the idea of reducing the number of items simply because in many classes, it was observed that many of the items were responsible for an overall high or low response on the attitude scale. For example, within Class 1, potable water was listed as one of several items. Visual inspection of the responses indicated that this should probably have been included as its own item since respondents listed it as very important across all operations and all factors. Because the United Nations High Commission on Refugees (UNHCR), NATO, and other organizations are working on packages that contain the supplies and services to be used in various types of operations, it would be worthwhile to try and synthesize the items in these packages and the items addressed in this survey.

This type of effort could also be more productive if it was administered from a more authoritative position. If the Joint Staff (J-4) were to direct commands at all levels to complete these surveys, the response rate from the military side could be greatly improved. On the civilian side, the United Nations Institute for Training and Research (UNITAR) and NATO frequently sponsor courses and conferences regarding Peace Operations. Someone studying related course work as opposed to undergoing the strain of an ongoing operation would probably be more likely to take the time necessary to fill out a lengthy survey. Following these two courses of action should result in a higher

response rate and would allow the stratification of civilian and military organizations. This would also allow some control of the sample population so experience levels and organizational levels of the respondents could be taken into account.

The way the survey is administered could be changed as well. Mailing surveys can be an expensive and time consuming effort. The same survey could have been designed in a format that would have allowed transmission over the internet. It is fair to assume that a majority of potential respondents either have access to the internet or at least some sort of electronic mail system. One of the concerns of mailed surveys is that it is difficult for the respondent to ask questions or get clarification on a survey item. The internet could allow an interactive way to clarify the survey. Much more information could be made available in an electronic document that would only need to be accessed if the respondent has a particular question. In addition, a quick electronic mail address to the instrument administrator would allow other questions to be asked. It was found in this survey that when respondents did take the time to call with questions, there was usually a lag before a response could be provided. The primary benefit of this method would be to reduce the cost of mailing a large number of surveys, many of which will not be returned.

The final step that must be taken is to thoroughly pursue nonrespondents in future efforts. "Nonrespondents often differ from the respondents in many respects. Their exclusion will introduce systematic errors in the results". [Ref. 17] It is important to be able to monitor the progress of the survey and stimulate nonrespondents. Administration at a higher command level and utilization of the internet will both make this much easier.

VI. CONCLUSION

Although it is obvious that doctrine as well as the situation and environmental factors dictate logistics priorities, this study provides a way to quantify those priorities and better understand the relationships that exist between logistics classes. Because the experiment conducted was only a pilot study with a small sample size and due to the underlying variability associated with psychological attitudes, verification and validation are difficult. Authentication is beyond the scope of this pilot study as well. Some verification using the heuristic approach developed was possible and included in Chapter V. Discussion. Actual validation in some cases, particularly with the ordinal rankings of supplies and services across Level II Factors, was conducted and also discussed.

Complete validation for Level I Factors and the intersections of Level II Factors was not attempted and was beyond the limited scope of this research. Further validation and authentication would require significant expansion across the FSO and the possible application of other nonlinear techniques before the method could be applied to the entire Logistics Requirements Problem Space. Additionally, the number of dimensions and types of factors used in this experiment were fixed and may differ for other operations.

A desire to determine how some other factor affects the logistics priority if others are deemed critical would not be practical without eliminating one or more of those used in this study. There may be other critical dimensions and factors to this problem, such as the degree of conflict or the level of complexity of the operation. However, if the degree of conflict was to be measured in three subcategories; low, medium, and high; and added to the current dimensions, the Logistics Requirements Problem Space grows quickly to

83

5,616 cells . The dimensions chosen were researched and logisticians were queried to see what types of factors would affect logistics in OOTW; but, these methods could be used on any dimensions. It is the length of the survey necessary to measure all of those dimensions that quickly becomes restrictive.

There might also be different intervals or category sizes for the dimensions used that would produce different results. For example, instead of measuring population sizes in unequal intervals, equal 1,000 person increments could be measured. This expands the size of the original problem, but might result in slight differences in the relative priorities. However, results indicate that population size and duration were both measured accurately. Because the scale values were either increasing or decreasing as a function of population size, there is no reason to believe that would significantly change. Changing the climate, on the other hand, may produce very different results if the subcategories were further broken down into temperature ranges instead of climate descriptions. This is true because of the obvious nonlinear relationships of scale values for different climates. A visual inspection of the climate data shows that for each logistics class, there is probably a function with higher scale values in the extremes and a minimum at the median. Again, the worth of expanding the number of categories to include intervals of temperature ranges instead of three general climatic descriptions is questionable at best. If it can be agreed that the nonlinear relationships exist and all operations can be sufficiently classified using the present categories, then for the purposes of modeling and simulation, the results are tractable and can be used. It would be unusual to find a person, much less a model or

simulation, who thinks of or that defines the environment associated with an operation in terms of specific temperature ranges.

This study has provided the proof of concept and serves as the basis to recommend further research. It has been shown that it is possible to quantitatively define the logistics requirements in a portion of OOTW and that changes in the relative priorities occur across at least three different operations. By expanding this method to include the FSO, models and simulations can be developed based on the priorities and the appropriate level of resolution can be determined more accurately. The priorities developed here can be associated with prepositioning of materials in potential hot spots or they can be used by planners in ongoing operations as a decision aid. The ideal situation is to build a variable resolution model based on these figures so planners and operators at all levels have access to the information they need without being overwhelmed by the details. The methodology demonstrated here has the capability to meet these needs.

APPENDIX A. COMPLETE SURVEY DESCRIPTION

The survey addressed three operations. The operation definitions used are in

Table 8. Scale value definitions are in Table 9. The six questions regarding Level I and

Level II Factors are contained in Table 10. Finally, a response sheet for each question was

provided and listed 61 items within the classes of supplies and services. The items

included are listed in Table 11.

Disaster Relief - Domestic
The overall mission is to promote human welfare, reduce pain and suffering, and to prevent loss of life or destruction of property from the aftermath of natural or man-made disasters. Generally, FEMA will be in charge of these missions, but support from other organizations such as military or local emergency services can be expected. These other organizations may bring specific capabilities to the field. A disaster may come in the form of hurricanes, tornadoes, fires, or earthquakes. Obviously, the scope of the assistance required will differ greatly from one to another of these disaster, however, the following questions are intended to determine how items might be prioritized, or how organizations view different portions of the mission.

Humanitarian Assistance
"Programs conducted to relieve or reduce the results of natural or manmade disasters or other endemic conditions such as human pain, disease hunger, or privation that might present a serious threat to life or that can result in great damage to or loss of property. In those operations in which authority through the Civil-Military Operations Center (CMOC) to provide essential humanitarian and technical expertise with the goal to contain the situation and transition to another lead agency." This includes Humanitarian and Civic Assistance defined as, "Incidental assistance to the local populace provided in conjunction with military operations and exercises." Examples include, Haiti, Somalia, Bosnia (the non-combat portions of), and the initial efforts to assist the Kurds in Iraq.

Noncombatant Evacuation Operations - Permissive
"Operations to relocate noncombatants from a foreign country or host nation. The environment may be permissive, uncertain, or hostile. The threat that necessitates the NEO may be a natural disaster or may be of human origin." For the following questions, the environment is permissive and the threat is a natural disaster.

Table 8. Operation Definitions

Value of 7: Should be considered Most Important - An item that requires complete visibility during the operation. If in reference to a particular item or category of items, this would indicate that the item should be tracked and controlled from procurement to consumption of the item and would require a central authority to monitor it. These could be considered the highest priority items.
Value of 4: Item is of Average Importance - This item is necessary to complete the operation, but does not require special consideration.
Value of 1: Should be considered the Least Important - Items that do not require immediate action. Shortages or an inability to complete the task would not hinder operations in the short-term.

Table 9. Amplifying Instructions for Use of Scale Entries on the Survey

Question #1: At what point in the timeline of the operation are the following items most needed? (Enter an "x" in the block that most applies). Although items may be needed throughout an operation, the point of this question is to ascertain at what time the items generally require the most effort on the part of the planner. Non-essential implies that the operation could be successfully completed without ever providing the item.

Additional Explanation: The time periods have been described as phases because the overall length of these operations can vary greatly. In general, a short operation with a small contingent of support personnel will have a short surge period where the initial movement of people and material does not require much time. An operation requiring large amounts of people or material may have a surge phase that is significantly longer. The phases can be described as follows:

Phase I & II: Predeployment, mobilization, and surge phase where initial planning and movement takes place. This is generally where the mission has been announced and transportation assets are identified. The initial requirements of material and support personnel are moved to the area of operations.

Phase III: Sustainment phase. Once the initial movement of people and material have taken place, this phase refers to the time when materials needed to sustain the operation begin to flow into the area of operations until the planned end of the operation.

Phase IV: Redeployment phase when the operation has been completed and the support forces and equipment are being removed from the area either to return home or to the next operation.

Question #2: Including both support forces and refugees, how would you rate the importance of planning for the item on the row relative to the size of the population in the columns? (Enter a number 1-7. 1 for least important and 7 for most important)

Although water may be as important to one person as it is to 10000, the point of the question is to determine if planning for water becomes more important as the size of the supported population increases.

Question #3: Please indicate the level of importance in planning on a scale of 1 to 7 of an item relative to the types of climate indicated. (1 for least important and 7 for most important)

Question #4: Please indicate the level of importance to planning of the following items relative to the expected duration of the operation on a scale from 1 to 7. (1 for least important and 7 for most important)

Question #5: Please indicate at which level of planning and support it is most important for the item to be considered. For example, what level should be acquiring or pushing the item? Indicate your answer by placing an "x" in the box or boxes that most apply. Please mark at least one box, but not more than two. The levels can be described as:

National/Strategic level - The item would be something requiring the approval or specific consideration by U.S. leadership or the international headquarters of an organization.

Operational level- The item would need approval or specific consideration by the leadership in the regional area of the operation.

Tactical/Unit level - The item is best handled by the individual units providing assistance within the region of the operation.

Question #6: For both support and supported personnel, please indicate who would best be assigned responsibility for the following items by entering a "x" in the appropriate box or boxes. Enter an "x" in each box that applies.

**Table 10.** Complete Survey Questions for Each Operation

| Class 1	Class 2	Class 3- POL	Class 4
*Food requiring cooking *Food-Supplemental (ie. bread, milk) *Food-Fresh *Food-Meals Ready to Eat (MRE) *Food-with cultural requirements (ie. kosher) *Potable Water *Non-potable Water *Utensils	*Uniform Articles *Clothing *Blankets *Tentage *Housekeeping supplies	*Vehicle Use *Power Generation *Maintenance *Hazardous Material *Heaters	*Building Materials *Sandbags, Concertina, and barbed wire *Command and Control Facilities *Hardening of existing structures *Housing (if tents not in use) *Latrines *Kitchens *Storage facilities *Medical Facilities *Heating equipment *Protective Barriers
Class 5- Ordanance	Class 6 Hygiene Items	Class 7 - Support Equipment	Class 8 - Medical
*Air *Ground *Riot Control (mace/batons/smokes *Security package w/ small arms ammo	*Morale kit (candy,toothpaste,gum,etc.) *Shaving kits (razors,toothbrush,soap)	*Trucks for personnel and supply transport *Forklifts *ROWPU's (Revese-Osmosis water purification unit) *Wreckers *Generators *Refrigerated Containers	*Military corpsmen for treatment of military personnel only *Follow-on supply to military corpsmen *General beds w/ equipment for adults *General beds w/ equipment for children *General beds w/ equipment for elderly
Class 10 - Humanitarian specific items			Transportation
*Contracted transportation *Contracted food preparation *Contracted fresh food supplies *Nonmilitary program materials *Reading/Recreational materials			*Military airlift *Contracted airlift *NGO/PVO/Private airlift *Military Sealift *MSC/Contracted Sealift *NGO/PVO/ Sealift *Military Ground transportation *Contracted Ground transportation *NGO/PVO ground transportation

Table 11. Logistics Items Included in Survey

APPENDIX B. RESPONSE FREQUENCIES FOR PHASE OF THE OPERATION

In all charts, the vertical axis represents the proportion of responses in a category.
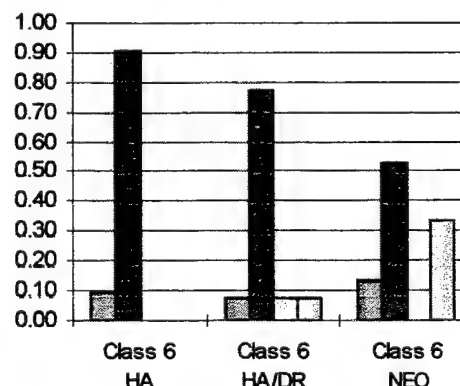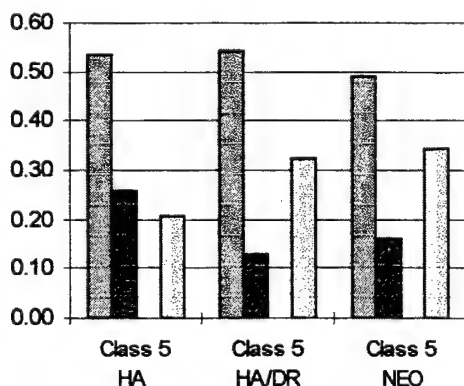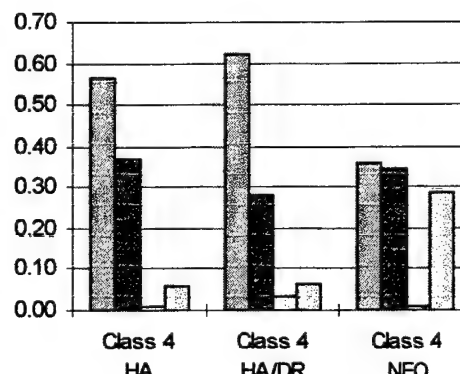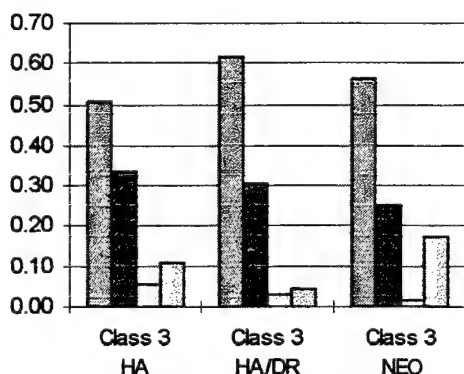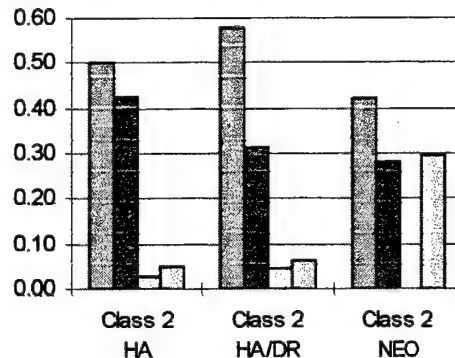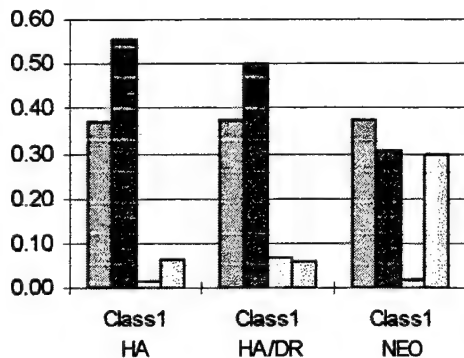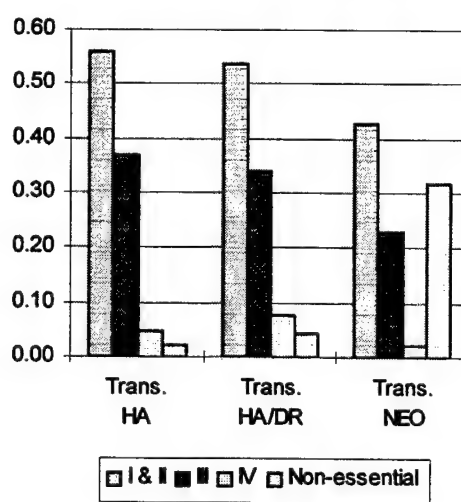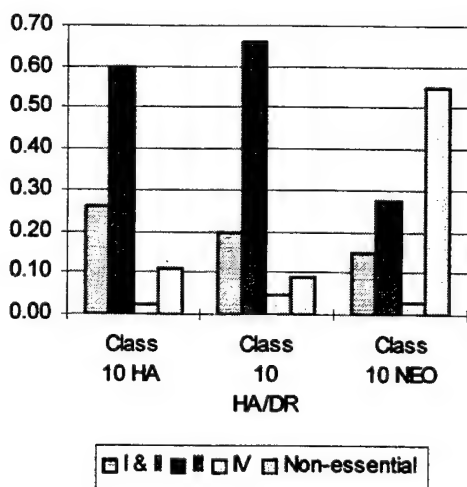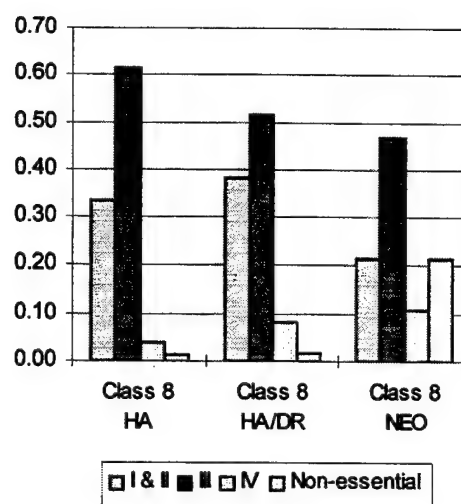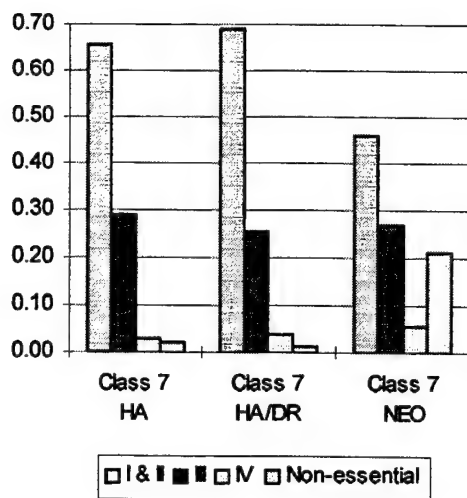
APPENDIX C. RESPONSE FREQUENCIES FOR PLANNING LEVEL
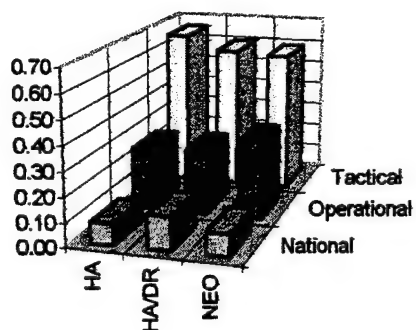
These charts show the response frequencies for the level of planning; national, operational, or tactical, that the respondent indicated was most appropriate for that logistics class. The vertical axis in all cases is the proportion of responses.

Class 1
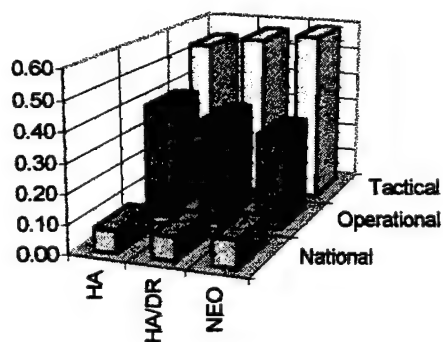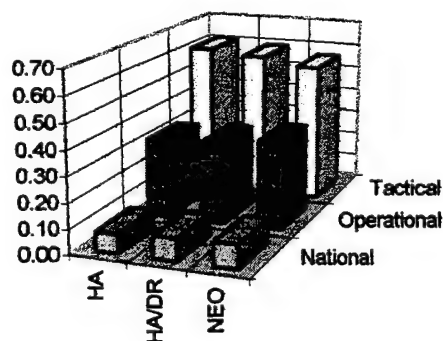
Class 2
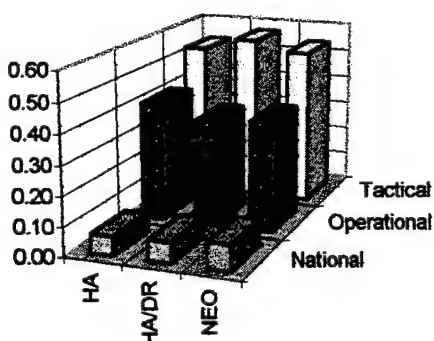
Class 3
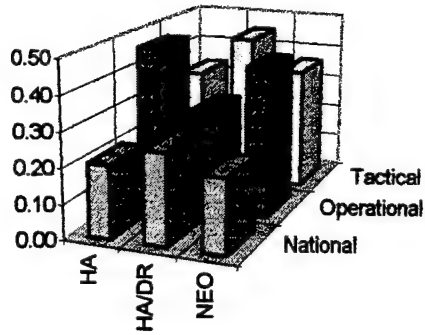
Class 4
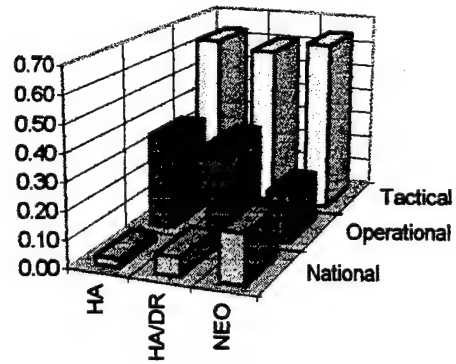
Class 5
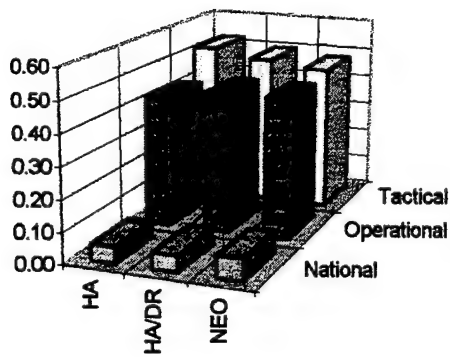
Class 6
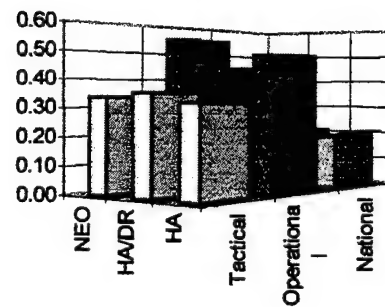
Class 7

Class 8

Class 10
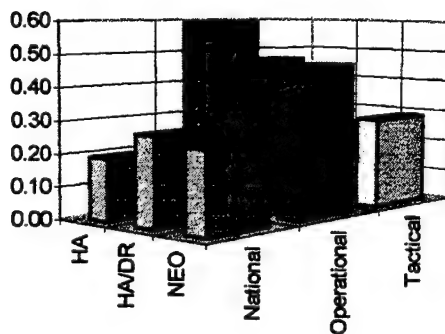
Transportation
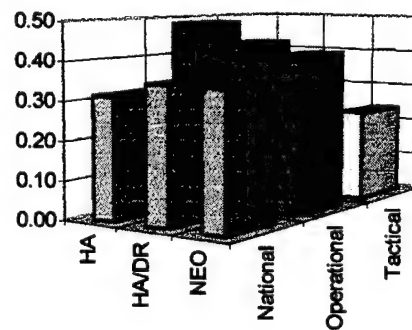
APPENDIX D. RESPONSE FREQUENCIES FOR LEVEL OF SUPPORT

These charts show the appropriate level of support for items based on the frequency of the responses. They are presented by class of supply or service for all three operations. The x-axis on the charts is labeled "M" for military, "O" for OFDA/FEMA, "CF" for coalition forces, "N/P" for NGO/PVO, and "HN" for Host Nation. The y-axis shows proportions of responses.

Class 1
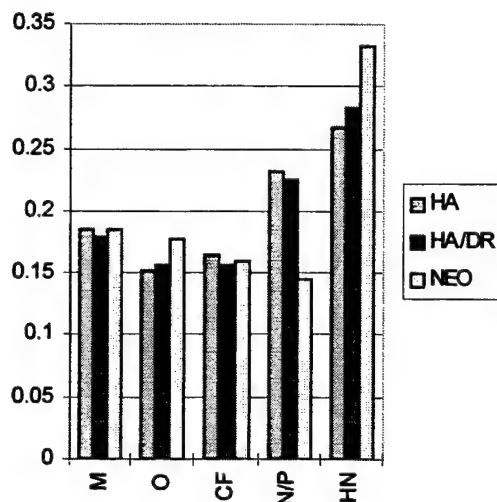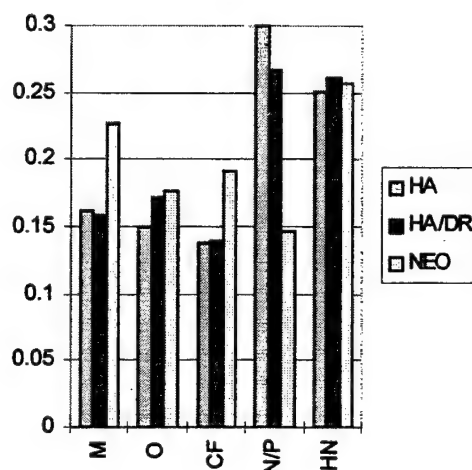
Class 2

Class 3

Class 4
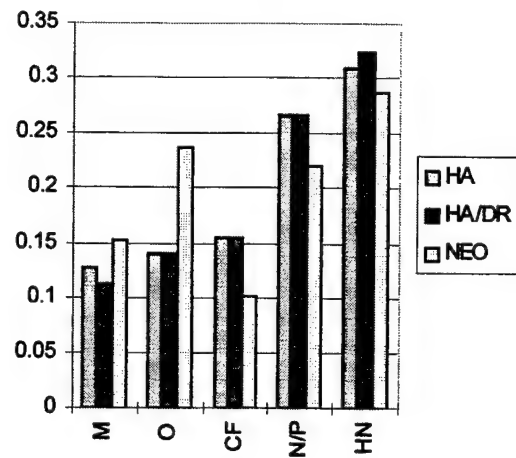
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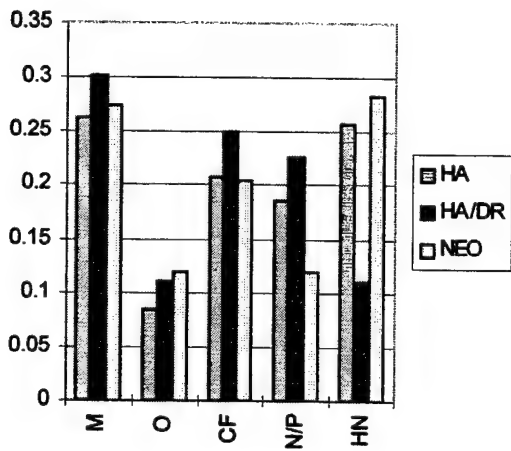
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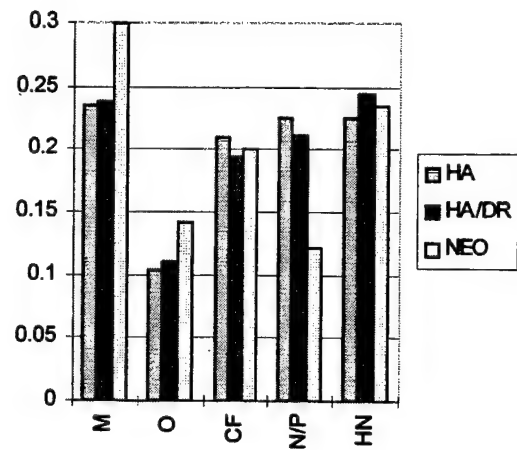
Class 7

Class 8

Class 10
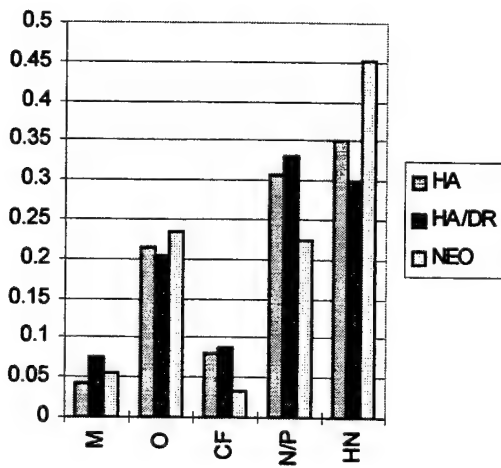
Transportation
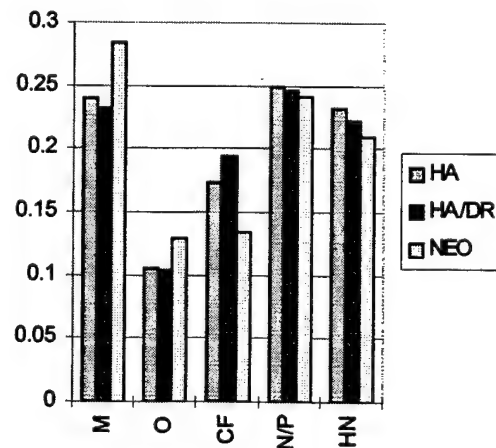
APPENDIX E. MEAI SCALE VALUES FOR POPULATION SIZE

All scale values (S) and interquartile ranges (Q) were calculated using MEAI. It would be possible to decrease the Q values by stratifying the samples or refining the survey questions.

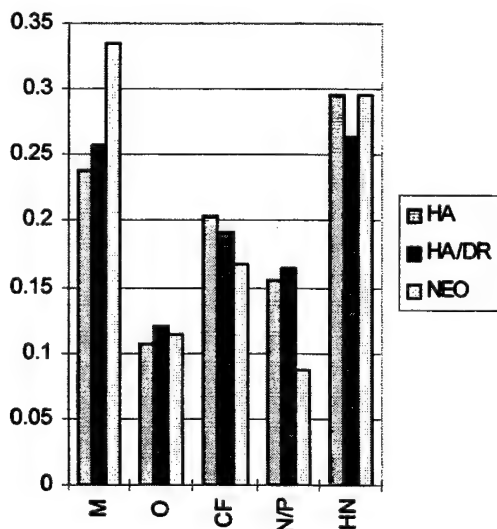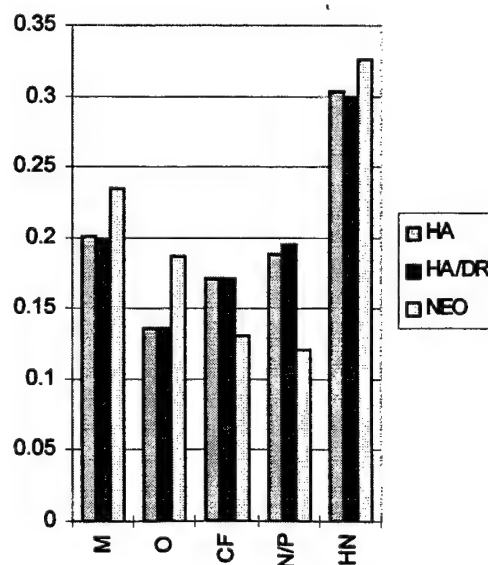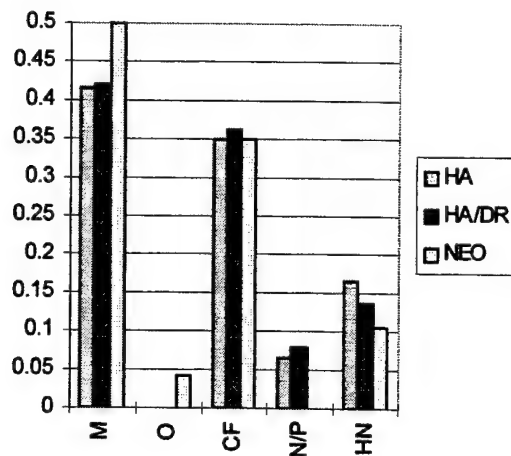| Humanitarian Assistance Operation					Humanitarian Assistance/Disaster Relief Operation					Noncombatant Evacuation Operation				
		Population Size					Population Size					Population Size		
Logistics Class		<1k people	1-10k people	>10k people	Logistics Class		<1k people	1-10k people	>10k people	Logistics Class		<1k people	1-10k people	>10k people
1	S	4.34	5.21	5.84	1	S	4.50	5.03	5.43	1	S	4.05	4.27	4.88
	Q	3.62	2.71	3.02		Q	3.16	2.74	2.60		Q	4.42	3.76	3.51
2	S	4.31	5.08	5.38	2	S	4.33	5.08	5.29	2	S	3.85	4.36	4.42
	Q	1.65	1.81	2.38		Q	1.63	2.08	2.42		Q	2.96	2.76	3.08
3	S	4.34	5.10	5.76	3	S	4.48	5.38	5.81	3	S	4.33	5.08	5.69
	Q	2.94	2.40	2.31		Q	2.46	1.80	1.96		Q	3.05	2.70	2.45
4	S	3.74	4.90	5.49	4	S	4.09	5.21	5.57	4	S	3.62	4.32	4.72
	Q	2.74	2.60	2.84		Q	2.23	2.54	2.49		Q	2.37	3.18	3.64
5	S	1.72	3.50	4.33	5	S	2.00	3.10	3.93	5	S	3.73	4.30	4.70
	Q	3.10	3.88	4.88		Q	3.28	3.92	4.71		Q	3.57	4.17	4.35
6	S	4.00	4.50	4.72	6	S	3.70	4.00	4.38	6	S	3.90	4.28	4.40
	Q	2.89	2.00	2.42		Q	2.42	1.94	1.63		Q	1.95	1.83	1.80
7	S	3.88	5.00	5.86	7	S	4.30	5.03	5.65	7	S	4.03	4.88	5.41
	Q	2.42	2.32	2.35		Q	1.53	1.53	1.90		Q	2.34	2.38	2.65
8	S	3.88	5.25	6.00	8	S	4.33	5.56	5.95	8	S	3.38	4.21	4.71
	Q	3.66	2.76	2.77		Q	3.29	2.89	2.48		Q	2.68	2.21	2.59
10	S	3.23	4.25	4.89	10	S	3.63	4.78	5.29	10	S	2.93	3.58	4.00
	Q	2.91	2.53	2.90		Q	2.67	2.55	2.86		Q	2.67	3.45	4.53
Trans.	S	3.00	3.91	5.16	Trans.	S	3.60	4.62	5.47	Trans.	S	3.71	4.82	6.17
	Q	3.11	3.12	3.55		Q	2.93	2.59	2.63		Q	2.64	2.87	2.58

APPENDIX F. MEAI SCALE VALUES FOR CLIMATE

The scale values (S) and interquartile ranges (Q) related to the question that asked for attitudes as the climate changed. Large interquartile ranges can be reduced by refining the survey questions or stratifying a larger sample of respondents across particular items.

Humanitarian Assistance Operation				
		Climate		
Logistics Class		Tropical	Moderate	Cold
Class 1	S	4.30	4.44	4.19
	Q	3.85	3.33	3.93
Class 2	S	3.38	3.78	5.61
	Q	2.46	2.40	3.26
Class 3	S	3.47	4.22	5.53
	Q	3.62	2.92	3.75
Class 4	S	3.76	4.10	5.16
	Q	3.10	2.61	3.93
Class 5	S	3.30	3.59	3.93
	Q	3.75	3.53	4.08
Class 6	S	3.50	3.21	3.10
	Q	2.67	2.33	3.25
Class 7	S	4.95	4.50	4.75
	Q	2.85	2.19	3.25
Class 8	S	4.63	4.33	5.19
	Q	3.34	2.26	3.31
Class 10	S	3.69	3.82	3.75
	Q	3.14	3.29	3.94
Transportation	S	4.02	3.87	3.98
	Q	2.92	2.83	3.66

Humanitarian Assistance/Disaster Relief Operation				
		Climate		
Logistics Class		Tropical	Moderate	Cold
Class 1	S	4.06	4.26	4.29
	Q	3.36	2.91	3.30
Class 2	S	3.30	3.47	5.54
	Q	2.49	2.15	3.36
Class 3	S	3.32	4.13	5.36
	Q	3.33	2.15	3.31
Class 4	S	3.93	4.26	5.23
	Q	2.78	2.21	3.13
Class 5	S	3.50	3.77	3.72
	Q	3.60	3.00	4.00
Class 6	S	2.83	2.88	2.88
	Q	2.43	1.96	1.96
Class 7	S	4.79	4.37	4.76
	Q	2.64	1.85	2.69
Class 8	S	4.69	4.37	4.79
	Q	2.95	2.18	2.86
Class 10	S	3.45	3.53	3.55
	Q	2.73	2.09	2.51
Transportation	S	4.19	4.17	4.35
	Q	2.62	2.57	2.82

Noncombatant Evacuation Operation				
		Climate		
Logistics Classes		Tropical	Moderate	Cold
Class 1	S	4.12	4.27	4.12
	Q	3.95	3.64	4.16
Class 2	S	3.43	3.83	4.90
	Q	2.89	2.27	3.60
Class 3	S	3.86	4.10	5.39
	Q	2.78	2.54	3.13
Class 4	S	3.46	3.78	4.39
	Q	3.14	2.68	3.65
Class 5	S	4.08	4.08	4.00
	Q	3.46	3.29	2.81
Class 6	S	3.72	3.64	3.64
	Q	2.00	2.33	2.50
Class 7	S	4.50	4.05	4.30
	Q	3.07	2.35	3.50
Class 8	S	3.88	3.88	4.13
	Q	2.94	2.33	3.19
Class 10	S	3.03	3.10	3.10
	Q	2.98	2.93	3.93
Transportation	S	4.61	4.40	5.03
	Q	3.33	3.23	3.33

APPENDIX G. MEAI SCALE VALUES FOR DURATION

The scale values (S) and interquartile ranges (Q) for the responses relative to a changing duration in the three operations are included here.

Humanitarian Assistance Operation				
		Duration		
Logistics Classes		<60 days	61-180 days	>180 days
Class 1	S	4.65	4.95	5.43
	Q	2.64	2.73	2.67
Class 2	S	3.53	4.40	5.18
	Q	1.95	2.52	3.39
Class 3	S	4.00	4.72	5.29
	Q	2.47	2.47	2.88
Class 4	S	3.94	5.10	5.58
	Q	2.42	2.51	2.57
Class 5	S	3.40	3.96	4.17
	Q	3.53	3.89	4.75
Class 6	S	3.28	5.00	5.50
	Q	1.83	2.18	2.29
Class 7	S	4.58	5.79	6.23
	Q	2.96	2.04	2.08
Class 8	S	3.81	5.66	5.91
	Q	2.59	2.28	1.99
Class 10	S	3.25	5.10	5.98
	Q	1.94	2.66	1.95
Transportation	S	3.61	4.31	4.82
	Q	2.71	2.51	3.29

Humanitarian Assistance/Disaster Relief Operation				
		Duration		
Logistics Classes		<60 days	61-180 days	>180 days
Class 1	S	4.54	5.06	5.90
	Q	3.17	3.24	2.75
Class 2	S	3.72	3.97	4.38
	Q	2.66	2.29	2.38
Class 3	S	3.95	4.53	4.91
	Q	2.47	2.05	2.24
Class 4	S	3.94	4.77	4.98
	Q	2.71	2.75	2.45
Class 5	S	2.90	3.28	3.59
	Q	3.51	3.63	3.53
Class 6	S	2.61	4.06	5.00
	Q	1.49	2.20	2.65
Class 7	S	4.79	5.30	5.41
	Q	3.14	2.14	2.09
Class 8	S	3.78	5.54	5.91
	Q	2.59	2.55	2.44
Class 10	S	3.13	5.00	5.78
	Q	1.94	3.46	2.45
Transportation	S	4.06	4.43	4.61
	Q	4.32	2.36	2.56

Noncombatant Evacuation Operation				
		Duration		
Logistics Classes		<60 days	61-180 days	>180 days
Class 1	S	4.14	5.03	6.35
	Q	4.35	2.88	2.32
Class 2	S	3.42	4.19	4.91
	Q	3.35	1.99	2.95
Class 3	S	4.10	4.94	5.81
	Q	3.21	2.64	2.46
Class 4	S	3.67	4.80	5.88
	Q	3.10	3.39	3.53
Class 5	S	4.58	4.10	4.50
	Q	3.79	4.35	4.29
Class 6	S	3.30	4.90	6.67
	Q	2.86	2.91	2.08
Class 7	S	3.95	5.63	6.37
	Q	3.63	2.73	1.86
Class 8	S	3.07	4.75	6.50
	Q	2.33	3.25	2.60
Class 10	S	2.41	4.36	6.50
	Q	1.91	3.16	2.08
Transportation	S	4.58	4.93	4.95
	Q	4.18	2.32	2.95

APPENDIX H. SENSITIVITY OF LOGISTICS CLASSES

These charts represent the impact of the three Level II Factors on the logistics

classes for each of the operations. The higher values indicate the greatest sensitivity.

Noncombatant Evacuation Operation

(Chart: Sum of Absolute Differences vs. Logistics Classes, with series Duration, Climate, Population)
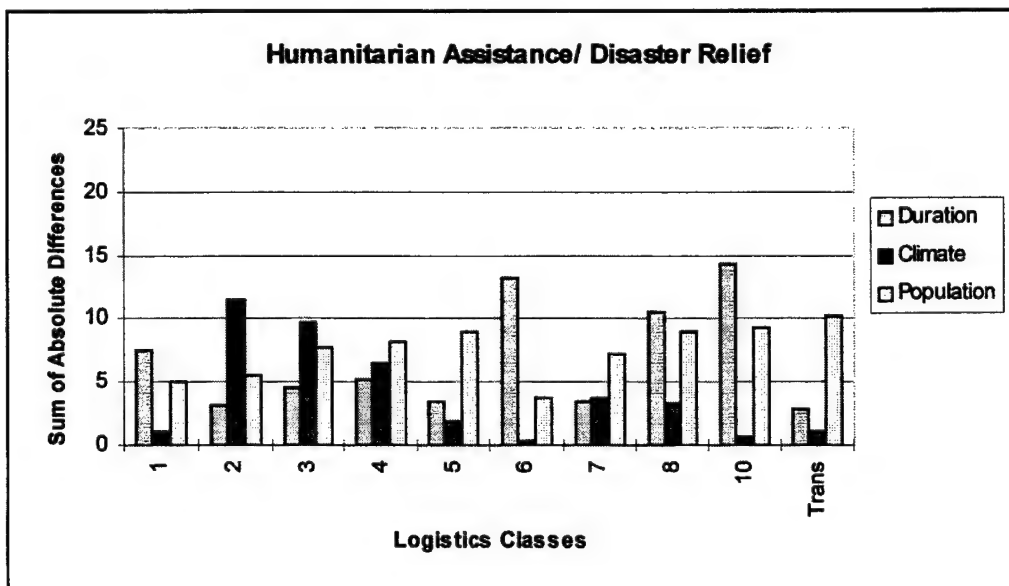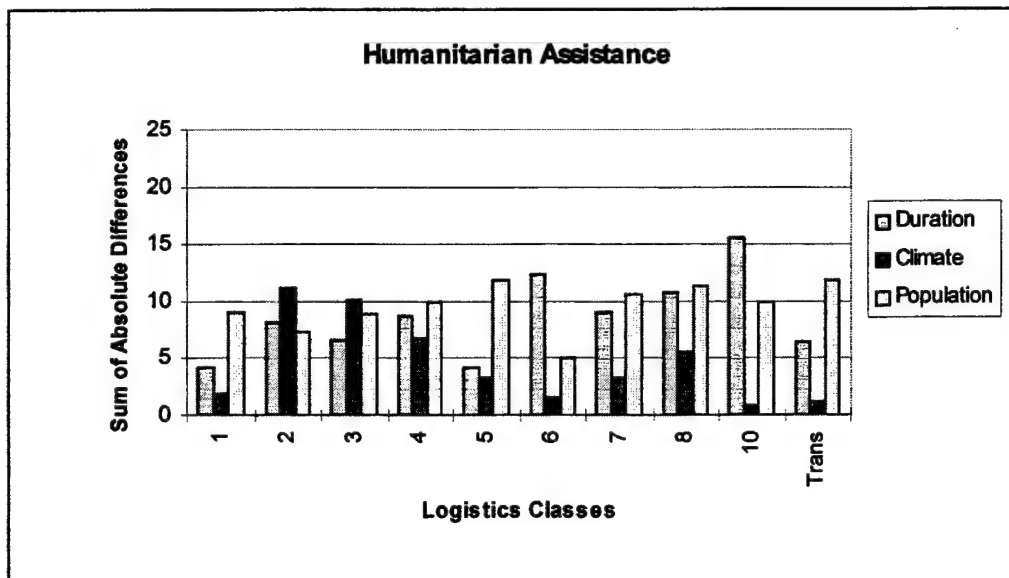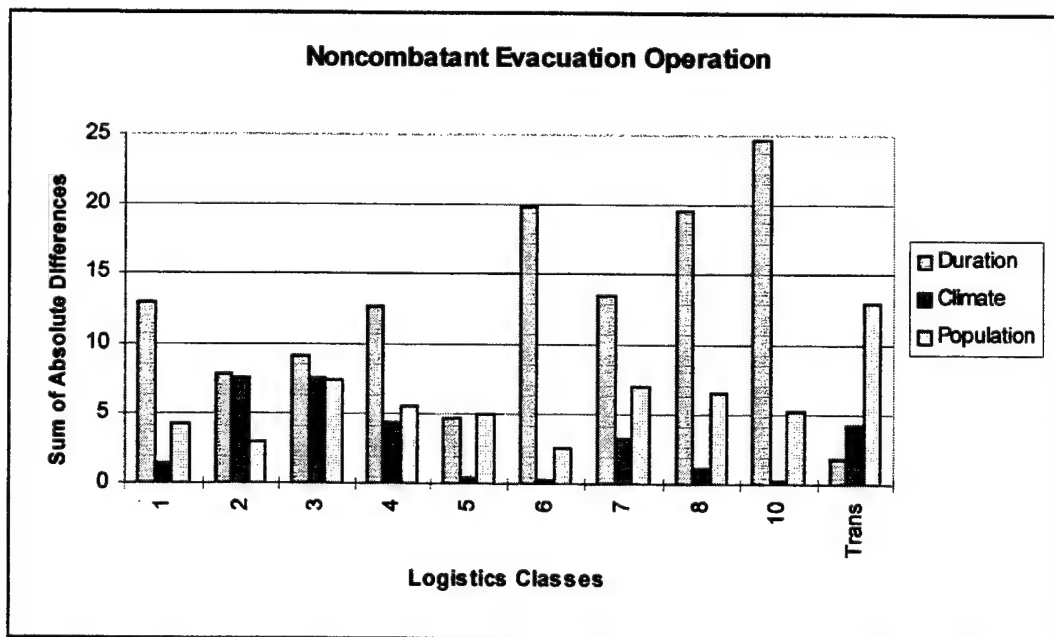
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